1991 ANNUAL REPORT

Alberta

OIL SANDS TECHNOLOGY
AND RESEARCH AUTHORITY

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Alberta

OIL SANDS TECHNOLOGY
AND RESEARCH AUTHORITY

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TO HIS HONOUR
T. GORDON TOWERS
LIEUTENANT GOVERNOR OF THE PROVINCE OF ALBERTA

Sir:

I have the honour to submit the Annual Report of the ALBERTA OIL SANDS TECHNOLOGY AND RESEARCH AUTHORITY for the fiscal year ended March 31, 1991.

Respectfully submitted,

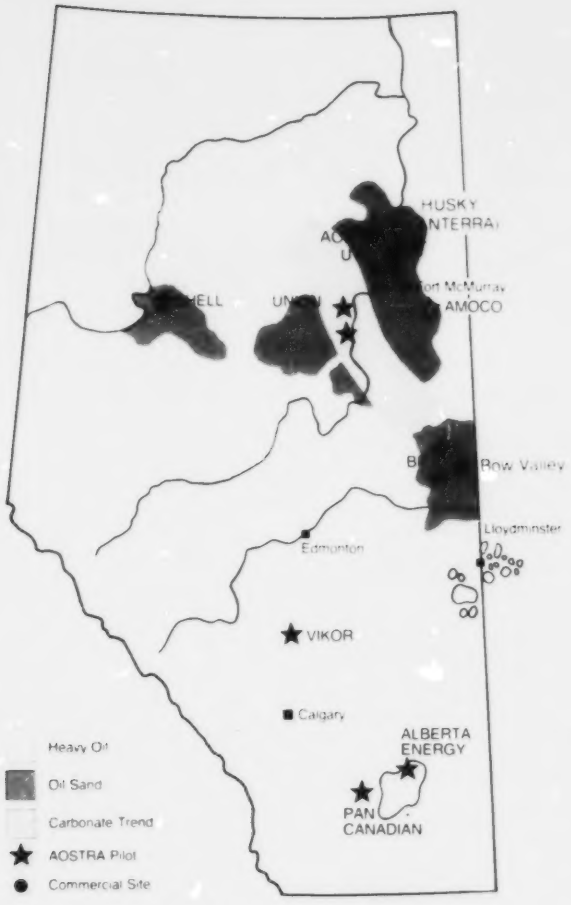
RICK ORMAN
Minister of Energy

Foreword

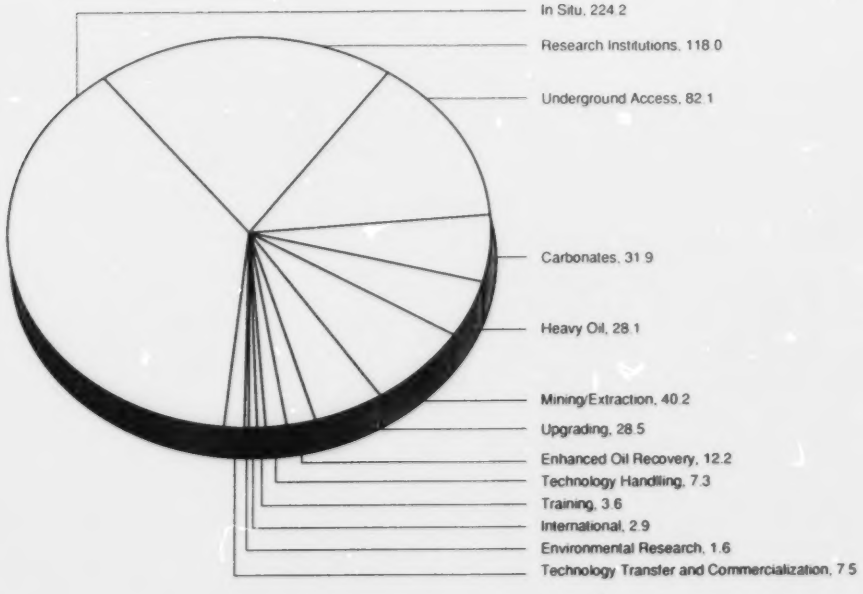
On January 14, 1974, The Premier of Alberta announced the availability of $100 million to develop new technology for the recovery and processing of petroleum from the Alberta oil sands. The terms and conditions for the disbursement of these funds are described in the Oil Sands Technology and Research Authority Act, passed by the Legislature in June 1974 and since amended to include the recovery of heavy oils and the enhanced recovery from conventional petroleum reservoirs. Additional funds have since been dedicated by the Alberta Government to permit the funding of longer term programs.

AOSTRA Field Pilot Projects

Figure 1



Commitments from AOSTRA Research Fund to March 31, 1991 ($ Millions)



Report of the Chairman and Chief Executive Officer

To the Honourable Rick Orman
Minister of Energy

Dear Mr. Minister:

I have the honor of presenting the Annual Report of the Alberta Oil Sands Technology and Research Authority (AOSTRA) for the fiscal year ending March 31, 1991.

The past year has been a very active and successful one for AOSTRA, with several of its major projects reaching commercial application. The technical viability of several other projects has been adequately demonstrated, and will undoubtedly lead to commercial operations when market conditions permit. These commercial successes represent the culmination of long periods of research, development, and demonstration which in one important case extended over 15 years. The ability to carry these projects through to fruition is a tribute to the wisdom and foresight of the Alberta Government of the time, in providing AOSTRA with assured long-term funding. This provision enabled AOSTRA to maintain base support to its industry partners through a lengthy research and development period, and then to increase it significantly when the more costly development stage was reached.

Despite uncertain market conditions and depressed prices for raw bitumen, industry interest in the development of improved technology for future operations has remained high. A number of very promising new applications have been received during the past year, together with proposals for extending existing projects into new phases. For the first time in its history, AOSTRA's participation in joint projects with industry has been much more limited by the availability of matching funds than by the technical attractiveness of the applications.

The organizational changes which I outlined in my last report have now been fully implemented. These were designed to facilitate our increasing emphasis on marketing and commercialization of technology, and there is every indication that the organization is working well. It is my expectation that our current organization will serve AOSTRA's needs with only minor modifications until such time as there may be a further major evolution in the scope of our activities.

A Management Audit was carried out near the end of the year by the Auditor-General to review and evaluate AOSTRA's procedures for selecting projects for funding, for monitoring project performance, and for reporting progress to the Authority Members. This Management Audit served to complement the Technical Audit which was carried out in 1985 by a panel of independent experts to review the technical appropriateness of AOSTRA's programs and the degree of success that was being attained in meeting the goals set out in the AOSTRA Act.

As a few highlights of AOSTRA's activities during the past year, two more field pilot projects have now reached the commercial stage of development and have been taken over by our industry partners. Both of these projects involve the enhanced recovery of conventional oil with carbon dioxide, and represent the first use of this technology in Alberta. The Vikor Resources Ltd. miscible carbon dioxide flood was started in the previously waterflooded and abandoned Joffre field in 1982, and has produced over one million barrels of oil from the pilot project. This project is now being expanded into a commercial operation. The other is the Ulster Petroleums immiscible carbon dioxide and waterflood project in the Retlaw field, which started in 1983 and was converted to commercial status in January 1991.

One new carbon dioxide enhanced oil recovery project has been initiated in cooperation with PanCanadian Petroleum Limited in the Countess M pool. The use of carbon dioxide for enhanced recovery is attracting increased interest since it is not only an effective technology for increasing oil production, but also a means of disposing of large quantities of carbon dioxide which would otherwise be vented to the atmosphere. A study of the technical and economic potential of this approach is now being carried out by AOSTRA with a group of 23 companies and government agencies. This study is evaluating the major sources of carbon dioxide in Alberta, the methods of capturing and purifying the gas, the potential applications in enhanced recovery, and storage in depleted gas fields to balance supply and demand. The capture and productive use of carbon dioxide in this manner would provide a solution to the "greenhouse gas" issue which would be particularly attractive to Alberta and Saskatchewan.

Two more field pilots which have now passed the million barrel milestone are the Norcen Energy Resources Bodo steamflood project and the Husky Oil Operations Kearl Lake steam drive project. The Norcen Bodo project is considered to have demonstrated its commercial viability, and the company expects to proceed with a commercial operation when market conditions permit. The Kearl Lake project has exceeded the performance targets that were originally established and has been the most productive in situ project in the Athabasca deposit to date. As of

the end of March, 1991 the operator was assessing the technical and economic feasibility of a commercial project.

The AWACT anti-water-coning technology has been successfully demonstrated in several field situations, and the final experimental phase in the Suffield Upper Mannville pool produced positive results in 9 out of 10 wells treated, with a projected incremental recovery of one-quarter million barrels of oil. As a result of these tests, the Alberta Energy Company initiated commercial AWACT treatments in 25 to 30 wells in the South Jenner pool, which presently has 125 producing wells.

The technology which offers the greatest long-term potential for in situ oil sands recovery is the twin-well, steam-assisted gravity drainage process which has been developed and tested in AOSTRA's Underground Test Facility. If the commercial length wells which are now ready for testing yield similar steam-oil ratios and production rates to the pilot tests, this process has the potential for the lowest-cost bitumen and the highest bitumen recovery of any method to date. It also results in the least disturbance of land surface and it relatively insensitive to depth or reservoir characteristics, so it is potentially applicable to a very large part of the total oil sand resource.

The gravity drainage process is particularly well suited to the underground access approach, but its greatest long-term application may be in precisely-located horizontal well pairs drilled from the surface. A group of companies now has a proposal before AOSTRA for a field test of this approach. Another spin-off from the Underground Test Facility (UTF) program is a field test by Chevron of its proprietary HASDrive technology, which was first pilot tested in the underground facility. AOSTRA has played a significant role in the development and testing of horizontal well technology in general, and there is every indication that this will become increasingly widely used in conventional as well as heavy oil production.

The AOSTRA Taciuk Processor (ATP) has continued to attract widespread interest for its spin-off applications in hydrocarbon waste treatment and cleaning of contaminated soils, both nationally and internationally. This technology has been licensed for commercial use in the USA as a method for oily waste cleanup. The 240-ton-per-day commercial processor built by UMATAC for Soil Tech Inc. has cleaned up 20,000 tons of PCB-contaminated soils at a site near Buffalo, New York and will process a further 18,000 tons at that location before being moved to the next project at Waukegan, Illinois. Construction has started on a 5-ton-per-hour mobile processor which will be operated at a number of locations in Alberta to clean up hydrocarbon contaminated sites and to carry out performance tests with municipal solid wastes and rubber tires. In addition, it will be used for on-site demonstration tests in its original role of oil sands and oil shale processing, as this is the primary objective as a mobile ATP facility

Upgrading of bitumen and heavy oil within Alberta will become increasingly necessary and attractive if the spread between heavy oil and synthetic crude prices continues to grow. In addition to tests with Alberta feedstocks in several of the most advanced upgrading processes available from process licensors, AOSTRA has had significant success in improving current technology. A novel technology for coke suppression has been developed which promises to remove the limitations to high conversion operation which have been experienced by existing Western Canadian upgraders. As a part of AOSTRA's Strategic Research Program with the Alberta Research Council, an entirely new upgrading process has been developed which shows great promise at the small pilot plant scale for reducing overall upgrading costs in a highly reliable high yield process.

Under favorable price regimes, the coprocessing of coal and bitumen may provide an economic advantage over upgrading of bitumen by itself. Industry interest in coprocessing is increasing, as evidenced by the participation of 12 industry and government partners in an AOSTRA-led study to examine the opportunities for coprocessing in Alberta.

During the past year, AOSTRA continued to pursue alternative technologies for the mining of oil sands and the subsequent extraction of bitumen, with a view to reducing costs and environmental impact. A major deterrent to the adoption of new technologies is the high cost of the large-scale field demonstrations which are needed to ensure a manageable level of technical risk, and it has become clear that industry is not prepared to take the lead in such developments without government participation. AOSTRA has been involved in the development of the OSLO New Ventures Dredge Mining-Cold Water Extraction Process for the past four years, but has been forced to withdraw from the project by budget restrictions in the coming year. Similarly, other proposed extraction process demonstration projects such as the Solvent Extraction Sand Agglomeration Process have been unable to proceed because of the costs involved.

In line with AOSTRA's policy of ensuring that all new technology meets contemporary environmental standards and that environmental concerns arising from existing commercial operations are addressed, AOSTRA is continuing to be actively involved in a diversity of projects in the areas of produced water treatment and re-use, preservation of air quality, and disposal of waste products. Key among these is a multi-party industry and government cooperative project to generate a common data base of information on the composition and properties of tailings sludge which can be used to identify the most effective and economical solutions to the sludge disposal problem.

In the Institutional Programs area, AOSTRA has had major success during the year obtaining sharply increased industry support for an expanded research program in improved recovery

methods for bitumen and heavy oils. This revised jointly funded research program, being conducted at the Alberta Research Council, will concentrate on high risk, high potential research which will substantially reduce the costs of producing bitumen and heavy oils.

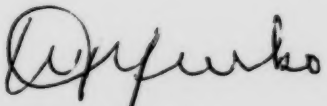
AOSTRA continues to provide excellent service to the industry in information storage and retrieval, oil sand and bitumen samples, and in the publication of journals, books, and other informative materials.

AOSTRA continues to expand its international activities and technology transfer and has obtained for Alberta a worldwide recognition as the centre of expertise in oil sands technology. This has led to increased sales of Alberta goods and services and a growing demand for AOSTRA technology such as that exhibited in the ATP and UTF technologies.

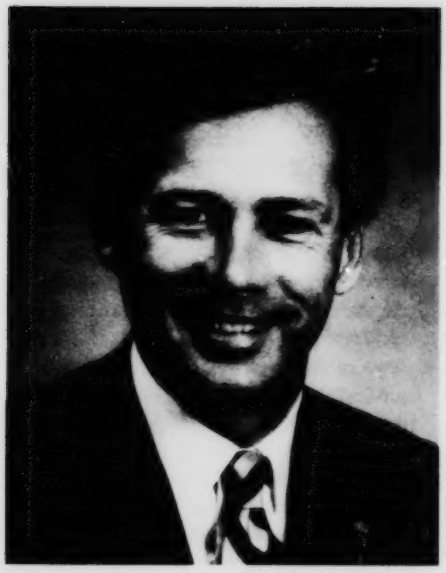
Looking to the year ahead, it is my intention to give high priority to the following areas of activity: demonstration and pre-commercial pilot tests of technology which has reached an advanced stage of development, so that it can be adopted commercially whenever market conditions permit; the solution of environmental problems which may be delaying new projects or attracting public concerns with existing activities; continuation of an active international technology exchange and marketing program so that Alberta companies will have access to overseas markets which are less dependent on the cycles of the domestic industry; and the maintenance of our institutional research programs at an adequate level to ensure a continued flow of new concepts for the next generation of technology.

I am confident that AOSTRA and its industrial and institutional partners have the necessary technical resources to accomplish all of these objectives successfully. Our main challenge will be to use our available funds and future allocations as effectively as possible in responding to the many opportunities that are now opening up for commercialization of our technology.

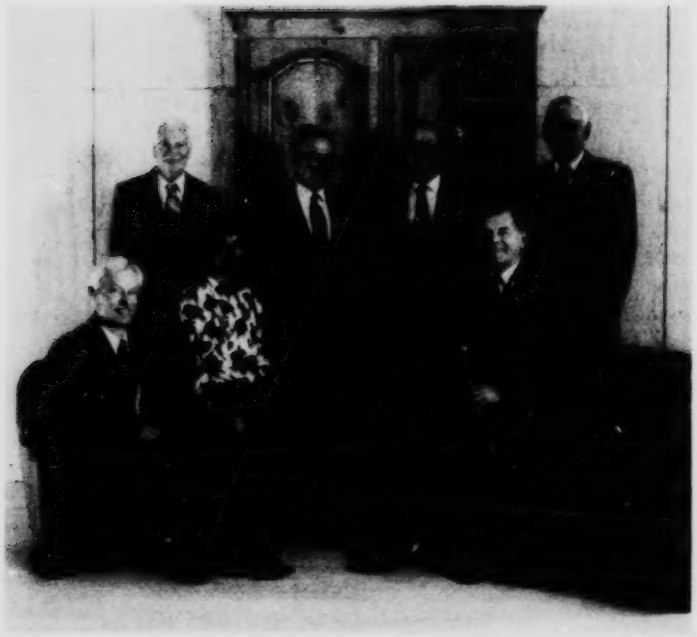
Respectfully submitted,



W.J. Yurko
Chairman and Chief Executive Officer



The Honourable Rick Orman
Minister of Energy



Members of the Authority
From left: R.W. Luhning, E.J. Wiggins, C. Dow Baker, H. Alger
R.M. Allison, W.J. Yurko, R.S. Aberg, (G.W. Shrake, not in photo).

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Vice-Chairman
Dr. R.W. Luhning

Members
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Mr. H. Alger
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Mrs. C. Dow Baker
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Report of Activities

1 IN SITU OIL SANDS RECOVERY PROGRAM

1.1 AOSTRA-Amoco Gregoire Lake Pilot Project

In 1984, Amoco Canada Petroleum Ltd., as operator, with AOSTRA and Petro-Canada as participants, initiated a steam injection project at Gregoire Lake on a site approximately 15 kilometres northwest of the earlier Block 1 pilot. A four-spot pattern of injection, producing, and observation wells was designed, in part, upon experience gained at the Block 1 pilot which tested the COFCAW process. Operations using steam and steam additives commenced in 1986 and continued through 1989. The project was designed to test the recovery of bitumen from a 41-metre thick McMurray sand reservoir located at a depth of 190 metres. Initial heat front movements in the reservoir were tracked through the application of 3-D seismic monitoring over the pilot area. The injection of a surfactant foam with steam was started in 1988 to improve steam sweep efficiency and to test for improved oil production rates and recovery.

AOSTRA and Amoco participated in an extension of the project which started in 1990. The purpose of the extension was to evaluate pressure cycling of the reservoir in conjunction with steam stimulation of the injection wells, to optimize surfactant usage, and to evaluate the effect of low temperature oxidation on plugging of the steam channels with air-steam injection. Testing of air-steam injection will proceed through the summer of 1991.

1.2 AOSTRA–Bow Valley Cold Lake Pilot Project

Bow Valley Industries Ltd., project operator, and AOSTRA, continued to participate in the operation of a pilot in the Cold Lake area of northeastern Alberta to test the recovery of bitumen from the Clearwater Formation. An earlier pilot tested the use of superheated steam, carbon dioxide, and a clay stabilization additive for the recovery of bitumen. A second inverted seven-spot pattern on larger spacing was drilled in 1986 to continue testing of the process. The extended project was operated until August 1990. A final project report is being prepared.

1.3 AOSTRA-BP Marguerite Lake and B-Unit Pilot Projects

BP Canada Exploration Ltd., as operator, with AOSTRA, Dome Petroleum Limited (now Amoco Canada Petroleum Company Ltd.) and PanCanadian Petroleum Limited, as participants, conducted the Marguerite Lake pilot project to test bitumen recovery from the Clearwater Formation by steam stimulation followed by wet combustion. Later, oxygen combustion was also tested. The steam recovery technology developed at the Marguerite Lake pilot is being applied in the commercial Wolf Lake project which surrounds the pilot area. The steam and combustion technology is available for licensing.

BP, with AOSTRA and Petro-Canada Inc. as participants, operated the B-Unit single-well cyclic steam stimulation project in the Lower Grand Rapids Formation of the Cold Lake oil sand deposit. Based upon the encouraging results of the pilot which was located 10 kilometres north of the Marguerite Lake project, BP and Petro-Canada developed a 22-well steam stimulation project in the Grand Rapids Formation at a location adjacent to the Wolf Lake operation.

1.4 AOSTRA-Husky/Esso Kearl Lake Pilot Project

Operated by Husky Oil Operations, Ltd., (formerly Canterra Energy Ltd.),

Celebrating one million barrels, from left: J.M. Szpecht, Husky; G van der Voet, AOSTRA; W. Jazrawi, Esso; J.D. Scott, AOSTRA; J.L. Milne, Husky; R.W. Luhning, AOSTRA; E.R. Gagne, B.R. Noble, R.F. Goods, Husky; W.K. Good, W.J. Yurko, K.E. Kisman, AOSTRA; D. Kumar, Esso; and L.B. Cannon, Husky.

with AOSTRA and Esso Resources Canada as participants, the Kearl Lake pilot project is testing a steam drive process in the McMurray oil sands which are located at a depth of 150 metres in the area. The sands are 43 metres thick. The project is located 77 kilometres northeast of Fort McMurray.

Operation commenced in 1981 with the development of the "A" pattern, an inverted seven-spot pattern with seven steam injection wells and six producers. In 1985 the "B" pattern consisting of an inverted nine-spot pattern was developed and placed on operation. The "B" pattern was expanded in 1987 with the addition of two adjacent five-spot patterns. Special fracturing techniques were employed in the two new patterns and steam additives were also tested. Production continued through 1990 with production blow-down commencing in January 1991. Cumulative production from the project has surpassed 1.5 million barrels. The project will be shut down in mid-1991 and completed with the finalization of project reports.

1.5 AOSTRA-Shell Peace River Pilot Project

Shell Canada Resources Limited, with AOSTRA, Shell Explorer Limited (now Pecten Canada Limited) and Amoco Canada Petroleum Limited, as participants, operated the Peace River in situ pilot project which is located 30 kilometres northeast of Peace River. Successful testing of a modified steam drive recovery process was completed in 1985. The recovery process was based upon cyclic steam pressurization and a modified drive process. Using the pilot project technology, Shell Canada constructed a commercial project with a producing capacity of 1600 m^3/d. The recovery process has been applied to a 27-metre thick oil sand in the Bullhead Formation at a depth of 550 metres and it utilizes a 3-metre bottom interval of high water saturation for fluid communication.

1.6 AOSTRA-Unocal Buffalo Creek and McLean Pilot Project

The Buffalo Creek and McLean pilot projects located 100 kilometres west of Fort McMurray were operated by Unocal Canada Limited, with AOSTRA and Canadian Superior Oil Limited (now Mobil Oil Canada Ltd.) as participants, starting in 1977 and ending in 1986. Recovery tests were conducted in the Grosmont 2 and 3 Devonian carbonate formations to test the effectiveness of the steam stimulation, steam drive, and wet combustion processes for bitumen recovery. Due to mixed results of the field tests, the project was suspended in 1986 to evaluate the potential of future piloting in the area. Because of the huge bitumen reserve in the carbonates, AOSTRA is pursuing the development of a new project in this large resource.

1.7 AOSTRA Data Base System

AOSTRA has available a data base system called ADBS II, that is designed for management of data from in situ projects. The system is developed, operated, and maintained by the Computer Services section of AOSTRA in Calgary. Users include project operators, project participants, and AOSTRA internally.

Features of ADBS II include data loading, data storage, comprehensive reports, and a standard query language for data manipulation. The system architecture is based on the UNIX operating system and a relational data base management system. Customized versions of the ADBS have been ported to several UNIX computing platforms.

The ADBS II is continually enhanced, and during the past year a new graphics system (AGS) was developed. The AGS is designed for workstation use and provides "point and click" access for the user, within a windowing environment. The graphics component is also part of a new ADBS environment being developed by AOSTRA that provides integrated information on the desktop, including numerical project data, textual data, engineering and geological applications, utility software such as graphics and spreadsheets, and electronic mail.

There are currently over 195 project-years of data within ADBS II, representing the detailed operations of 20 projects. Authorized users can access specific project data at reasonable cost via dial-up access to AOSTRA's Calgary computing facility. Arrangements can also be made to copy requested data on standard computer media for transfer of data to user sites. Users must be project participants for the particular data accessed, since all data within ADBS II are confidential.

In addition to management of data from projects that have AOSTRA participation, ADBS II is available for license on external systems. In this case, AOSTRA staff install and support customized versions of the system on compatible computing systems at user sites.

AOSTRA welcomes industry inquiries regarding access to project data, and use of the data base system for in situ projects.

2 HEAVY OIL RECOVERY PROGRAM

2.1 AOSTRA–Alberta Energy Suffield Heavy Oil Pilot Projects

AOSTRA participated in the Suffield heavy oil combustion project which was operated by Alberta Energy Company Ltd. (AEC) on behalf of Amoco Canada Petroleum Company Ltd. (formerly Dome Petroleum Limited) and Westcoast Petroleum Limited. While production from the combustion pilot exceeded that which would have been expected from primary recovery alone, further combustion testing was not warranted. The project terminated in 1986. An analysis of the combustion project led to the development of anti-water-coning technology that is now being applied commercially and can be licensed from AOSTRA for application by interested parties.

In 1989, an additional heavy oil recovery test was started when AEC, AOSTRA, and Westcoast Petroleum initiated a hot water flood in an inverted four-spot pattern in the Suffield Block. The hot water flood was tested in a 33-metre thick heavy oil section of the Glauconitic sandstone reservoir which was underlain by water. The hot water flood project ended on December 31, 1990 and the results are being analyzed for summary in a final report.

2.2 AOSTRA-Mazzei Frog Lake Field Pilot

In April 1990, AOSTRA initiated a project with Mazzei Oil and Gas Inc., as operator, to test cyclic steam stimulation of the Mannville sand formation in the Lloydminster heavy oil sands. The project is located in the Frog Lake area of east-central Alberta in a 3-metre thick reservoir at a depth of 460 metres. Two cyclic steam injection tests were conducted on two wells. The production results of the steam stimulation tests are being compared to the results of heating by electro-magnetic methods in two adjacent wells. A post-project production analysis is now being conducted.

2.3 AOSTRA–Norcen Bodo Field Pilot

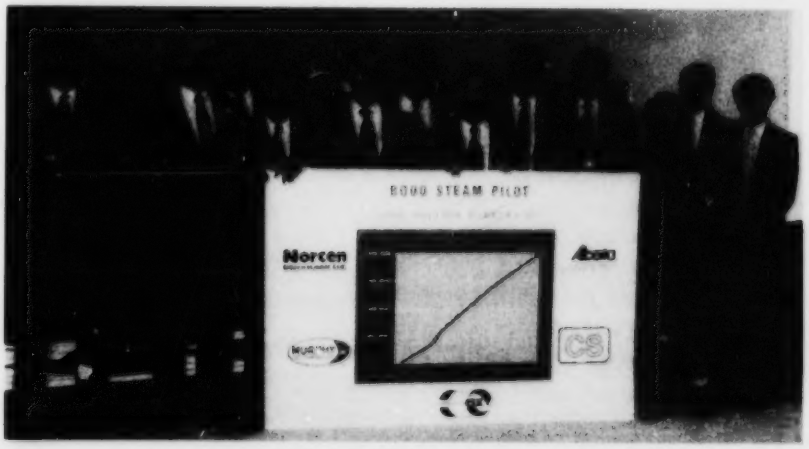
AOSTRA, Norcen Energy Resources Limited, Esso Canada Resources (formerly Texaco Canada Resources), Murphy Oil Company Limited, and Canadian Occidental Petroleum Limited are coordinating a steam flood project in the Bodo field in east-central Alberta. The test which is operated by Norcen is being conducted in a 15-metre thick McLaren sand in the Upper Mannville Formation at a depth of 720 metres.

The results of the steam flood will be compared with the results of an earlier combustion project operated until 1984 by Norcen. A nine-spot steam pilot similar in configuration to the combustion pattern was constructed offsetting the combustion pattern. Steam injection operations began in 1985 with four cycles of steam injection. The cyclic steam injection was followed by a steam flood which continued through 1990/91. In December 1990 the pilot project produced its millionth barrel of oil.

3 ENHANCED RECOVERY PROGRAM

3.1 AOSTRA-Amoco Cessford Caustic Polymer Flood

Single-well tracer tests conducted on a well in the Cessford Basal Colorado "A" Pool in 1980 indicated that residual oil saturation could be measured before and after caustic flooding. The results



With a graphic display of cumulative oil production leading up to the million-barrel milestone (from left) R. Morgan, Murphy Oil Company Ltd; R.W. Luhning, J.H. McKibbon, AOSTRA; G. Shopp, B. Cochrane, Norcen Energy Resources Limited; J.D. Scott, W.J. Yurko, AOSTRA; G. Harris, Canadian Occidental Petroleum Ltd; D.R. Barber, C. Dow Baker, T. Beale, G. Kwan, Norcen.

of these tests and further laboratory studies conducted by Hudson's Bay Oil & Gas Co. Ltd. (now Amoco Canada Petroleum Ltd.) indicated oil recovery could be further improved with the addition of polymer to the caustic flood.

A field project was initiated in the Cessford Basal Colorado "A" pool in 1986, with Hudson's Bay as the operator and AOSTRA and Sulpetro (now C.S. Resources) as participants. The injection of the caustic-polymer slug was completed in 1990. Fresh water is now being injected in the project and will continue through 1991. The gross costs for the incremental caustic polymer water flood are estimated to be $4.9 million.

3.2 AOSTRA–Canadian Hunter Ethel Lake "BHL"

Pool Horizontal Well

Canadian Hunter Exploration, as operator, with AOSTRA as a participant, drilled a long-radius horizontal well into the Ethel Lake "BHL" pool in 1988. The purpose of the test was to assess the commercial feasibility of exploiting low-permeability oil reservoirs with horizontal wells in an area where vertical wells have proven non-commercial. The well was successfully drilled but poor quality reservoir was encountered and the expected production potential of the well will not be realized.

3.3 AOSTRA–D.B. Robinson Industry Slim Tube Study

A nine-member cooperative industry-supported research program is being operated by AOSTRA to investigate the use of slim tube tests to evaluate conditions of miscibility, particularly in the transition zone in miscible floods. The contractor for the project is D.B. Robinson & Associates. The objective of the program is to demonstrate the feasibility of collecting and analyzing small samples of flowing fluids in a slim tube test in the transition zone between the solvent and the oil. A series of slim tube tests has now been completed on special test equipment that was designed and fabricated for the project.

3.4. AOSTRA-Gulf Fenn-Big Valley "D3-B"

Nitrogen Injection Project

Gulf Canada Resources Ltd., with AOSTRA as a participant, operated a nitrogen injection project in the Fenn-Big Valley "D3-B" pool which is located approximately 80 kilometres east of Red Deer. The objective of the project was to determine if the recovery of oil, natural gas liquids, sulphur, and gas could be improved by nitrogen injection through the maintenance of reservoir pressure, replacement of reservoir fluids by nitrogen, and the stabilization of fluid interfaces. The project was initiated in 1987 and extended in 1989 to test the effectiveness of nitrogen foam injection to further enhance recovery. A post-project analysis is now being conducted.

3.5 AOSTRA-Husky Asphaltene Solids Precipitation Project

Husky Oil Operations Ltd. (formerly Canterra Energy Ltd.) was the operator of a jointly supported research program with AOSTRA to conduct a laboratory study of precipitation of asphaltene in selected light oils when contacted by hydrocarbon solvents. The study was completed in 1990 at a cost of $310,480 by Hycal Energy Research Laboratories as contractor for the project. A mathematical model to predict the deposition of asphaltenes under various pressure and temperature conditions was formulated using an equation of state and data obtained from asphaltene solubility tests. A PC computer program was developed to predict the precipitation of asphaltenes based upon the mathematical model. The study and program are available for licensing to interested parties.

3.6 AOSTRA-PanCanadian Countess "B" Combustion Pilot

PanCanadian Petroleums Limited and LL & E Canada Limited are participants in the Countess "B" pilot which is being conducted to evaluate a wet combustion recovery process in the previously water-flooded Countess Upper Mannville "B" pool near Brooks, Alberta. The project which is operated by PanCanadian, was initiated in 1982 with a single combustion well surrounded by four producing wells. The project was expanded in 1990 with the development of two additional combustion wells.

AOSTRA is funding a research program to support the pilot project activities. The supporting research program included combustion tube tests, combustion front mapping, a post-combustion core well, geological studies, corrosion studies, numerical simulation modelling, core flow tests, and a production PVT sampling well for evaluation of the combustion process. The supporting research program will continue through 1991.

3.7 AOSTRA-Pfizer Profile Modification Studies

AOSTRA is participating in a project operated by Pfizer Canada Inc. to field test the modification of injection profiles in water flood injection wells by injecting a gelant slug into a highly permeable thief zone. The goal of the project is to demonstrate the effect of improved injection profiles on volumetric sweep and ultimate oil recovery. Negotiations are under way with field operators to identify suitable field candidates and to conduct the field tests which are expected to begin in mid-1991.

3.8 AOSTRA-Vikor Joffre Viking CO_2 Miscible Flood

Vikor Resources Ltd. is the operator of the Joffre Viking CO_2 miscible pilot project on behalf of AOSTRA and the unit participants. The pilot is testing the ability of a CO_2 miscible flood to recover tertiary oil from a 3-metre thick, previously water-flooded and abandoned reservoir containing light gravity oil.

CO_2 injection alternating with water injection (WAG process) commenced in 1984 in two inverted five-spot patterns each covering 65 hectares. The pilot demonstrated the ability of CO_2 to improve the recovery of tertiary oil from the relatively thin lower Cretaceous sandstone reservoir. The encouraging results led to the expansion of the project in 1985 and 1988. Further expansion of the project is being considered by the operator. A mobility control test using a foam surfactant was initiated in the original pilot in 1988. The pilot project was completed on December 31, 1990.

3.9 AOSTRA–Ulster Petroleums Retlaw Upper Mannville "V"

Immiscible CO_2 Project

Ulster Petroleums Ltd. (formerly Canadian Westgrowth Limited) is the operator of the Retlaw Upper Mannville "V" Unit Immiscible CO_2 Project on behalf of AOSTRA and the 10 unit participants. The project, located 30 kilometres northeast of Lethbridge, is the first immiscible CO_2 flood to be conducted in Canada. The objective of this project is to evaluate the performance of a CO_2 immiscible flood in a medium gravity water-sensitive reservoir. The injection of CO_2 which commenced in 1983 is being followed by water injection. The project became commercial on January 1, 1991.

AOSTRA is acquiring operating data on the project and has completed a preliminary analysis of project performance.

Celebrating one million barrels, from left: B. Lowden, Tiverton Petroleums Ltd.; G.A. Sim, Petro-Canada Inc.; E.H. Toews, Altex Resources Ltd.; W.J. Yurko, AOSTRA; K.D. Hutchinson, Altex Resources Ltd.; D.J. Stephenson, Vikor Resources Ltd. and ADJS Resources Ltd.; and U. Banner, Venwest Resources Limited. Other owners are Esso Resources Canada Limited, Jones Valley Resources Ltd., and Wellore Energy Inc.

From left: R.W. Luhning, AOSTRA; R.J. Davison, Canada Northwest Energy Limited; B.S. Anderson, W.J. Yurko, J.D. Scott, AOSTRA; D.C. Munro, Ulster Petroleums Ltd.; D.P. Komery, AOSTRA.

4 COMMERCIAL DEVELOPMENT

One of AOSTRA's key activities for this report year has been directed towards the commercialization of new improved technologies developed by AOSTRA and its industry partners.

Industry needs to be convinced that the new technology has no greater technical or environmental risk than the existing technology. It must also show potentially significant improvement in the return on investment. To achieve this level of technical confidence and economic viability the new approach has to be field demonstrated. This requires long-term planning, multiyear budgeting, and perseverance. All of this requires commitment by industry since commercial development of new technology today is in direct competition for funding with their existing conventional oil and gas production businesses.

AOSTRA is taking a proactive approach towards convincing industry leaders to continue and increase their participation in field demonstration projects towards commercialization of key AOSTRA technologies.

Presentations of technical papers at important conferences and displays at trade shows and conferences are several other approaches used by AOSTRA to convince industry's technical managers of the commercial readiness of AOSTRA-owned technologies.

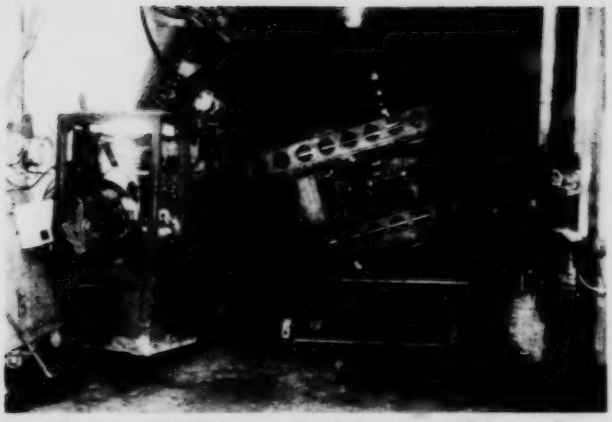
4.1 Underground Test Facility (UTF)

Over one trillion barrels of bitumen in the Athabasca oil sands near Fort McMurray have become accessible by using the technologies developed at AOSTRA's Underground Test Facility. These are the Shaft and Tunnel Access (SATAC) and Steam Assisted Gravity Drainage (SAGD) technologies utilizing commercial-length horizontal wells in the oil sands pay zone to recover bitumen in situ by a more efficient and cost-effective method.

The UTF project was initiated by AOSTRA in 1982 with a series of design studies employing mine access to provide for effective testing of horizontal-well in situ recovery processes. The positive results led to a commitment by AOSTRA to start construction of the UTF in 1984. Meanwhile, an industry steering committee consisting of 16 oil industry firms and AOSTRA also conducted a thorough evaluation. They confirmed that the commercial development of these previously inaccessible resources was technically and economically feasible by using the UTF technologies. During 1985, work continued on the mine construction and on the development of a custom drilling rig. This rig was designed to place commercial-length horizontal wells from the underground tunnel system.

In 1986, AOSTRA made a further commitment to test the SAGD process in Phase A of the project. The mine access facilities were completed and the custom drilling rig had been fabricated, field tested and reassembled down in the mine for drilling of the test wells.

The in situ process testing was initiated in 1987. Six Canadian industry majors, Amoco, Chevron, Mobil, Petro-Canada, Shell, Texaco, and CANMET, the Canadian Centre for Mineral and Energy Technology of the Department of Energy, Mines and Resources Canada, became participants in the Phase A program.



Specially designed drill rig starts borehole at about 15 degrees from horizontal; borehole levels off in the oil sands formation.

Enhanced geotechnical work and a separate test of Chevron's proprietary HASDrive process were added to the program. The underground drilling program resulted in successful placing of eight horizontal wells with significant advances in horizontal well technology. The SAGD and HASDrive were started up successfully in the late fall of 1987.

During the next two years both Phase A well tests proved to be unqualified successes. The SAGD process demonstrated a commercially viable combination of production rates, steam-oil ratios and ultimate recoveries. Hence, in 1989, the Phase B SAGD test program was initiated by AOSTRA. Phase B is designed to confirm the necessary drilling accuracy and scale-up in performance using the commercial-length (600-metre) wells.

Seven industry participants (Amoco, Chevron, Conoco, Esso, Mobil, Petro-Canada and Shell) joined AOSTRA to start Phase B construction in the spring of 1990. Construction and testing are scheduled for completion by mid-1994.

To date, all of the 550 metres of tunnel have been driven in the limestone beneath the oil sands deposit and secured. The six 600-metre horizontal wells have been successfully drilled and completed in the oil sands pay zone. These three well pairs are spaced 70 metres apart and each well pair consists of a production well 2–5 metres above the base of the oil sands and the steam injection well about 5 metres above the production well.

Engineering of the surface process facilities and underground piping is proceeding according to schedule. The first well pair is scheduled to start steaming in September 1991. Full capacity operation is expected to be achieved by September 1992. The horizontal wells and SAGD process will be performance tested till the end of March 1994 according to the original Phase B schedule. Total Phase B production of bitumen is expected to reach 2000 barrels per day (BPD).

The objective is to produce a dry bitumen during the Phase B test program. This will provide the highest value product and the revenue from the bitumen production sales will be used to offset Phase B operating costs.

A 4-inch natural gas pipeline to the UTF plant was installed to eliminate the need for using the higher priced trucked-in propane. The capital cost of $2.2 million will be recovered within less than one year of operation.

4.2 AOSTRA Taciuk Process (ATP)

The AOSTRA Taciuk Process technology has been developed over the past 13 years primarily to extract and partially upgrade bitumen from oil sands. Two other spin-off technologies have resulted in direct commercialization of the oily waste treatment application and near commercialization of oil shale processing.

About 20 million dollars have been required to develop this technology to its commercialization level. Over 15,000 tonnes of oil sands, oil shales, and oily waste materials have been tested in AOSTRA's ATP pilot plant in Calgary. This included scale-up development testing which has prepared the ATP technology for field demonstration of oil sands and oil shales processing, and commercial applications in the treatment of oily wastes. Outside Canada, much interest has been expressed in using the ATP technology for processing oil sands, oil shales, and oily waste materials. This includes the U.S.A., Australia, China, Russia, Trinidad and Tobago, Indonesia, and Estonia.

4.3 Oil Sands Processing Using ATP Technology

ATP technology is ready for field demonstration in the extraction and partial upgrading of bitumen from mined oil sands in Alberta. More than 15% of Canada's current oil production is produced from mined oil sands in Alberta. Development testing and economic comparisons of the ATP have shown it to be a technically, environmentally, and economically viable alternative to the currently used hot water extraction process.

AOSTRA is continuing discussions with industry lease holders aimed at field demonstration of the ATP technology towards commercial development of the oil sands mining leases. The ATP technology may also have certain beneficial applications in existing commercial mined oil sands projects which are utilizing the hot water extraction process.

4.4 Mobile ATP Demonstration Plant

A $5-million, 5-tonne per hour (TPH) mobile ATP plant was approved in 1990 and procurement and construction is currently under way. This demonstration plant is totally self-contained and can be trucked to and from a given site. The mobile ATP plant will be used primarily to field demonstrate the effective and efficient processing of mined oil sands resulting in a partially upgraded bitumen and clean sand. The objective is to demonstrate the operation of the ATP process plant at a lease processing freshly mined oil sands. The mobile ATP plant can be operated during the winter as well.

The mobile demonstration plant is expected to be fully constructed by late fall 1991. It will then be performance tested at AOSTRA's pilot site in Calgary and will be ready for commercial demonstration in early spring 1992.

During the intervals when the 5-TPH mobile ATP plant is not demonstrating mined oil sands processing, it will be utilized to treat the soil at hydrocarbon-contaminated industrial and oil field production sites in Alberta. The priority sites in Alberta will be those sites which have been inherited by the Alberta government and municipalities.

A business development plan is currently in progress to provide efficient utilization of the 5-TPH mobile ATP plant. This plan will include mined oil sands processing demonstrations, cleanup of hydrocarbon-contaminated sites, oil shale processing, and testing on processing rubber tires and municipal solid wastes.

4.5 ATP Application in Processing Oil Shales

Southern Pacific Petroleum (SPP) and Central Pacific Minerals N.L. (CPM) of Australia investigated more than 15 different technologies from five countries for the processing of the rich oil shale deposit in Queensland, Australia. They found that the ATP technology was the most technically and economically viable process for extraction of oil from oil shales.

In 1987 more than 1500 tonnes of Australian (Stuart) oil shales were processed in AOSTRA's 105-tonne-per-day (TPD) fixed pilot in Calgary. Due to highly successful test results, scale-up testing and technical and economic assessments during 1988 and 1989, SPP/CPM have undertaken to work towards construction of a 6000-TPD oil shale processing demonstration plant at Queensland, Australia. Construction is planned to start as soon as the operators secure government tax and royalty agreements and third-party project financing. SPP/CPM are also negotiating with an international engineering, procurement, and construction contractor to participate in the project as an equity owner. This demonstration project will produce more than 4000 BPD of shale oil products. SPP/CPM plan to increase the project capacity to 60,000 BPD synthetic crude in stages, using scaled-up multiples of the AOSTRA Taciuk Processor.

AOSTRA has licensed SPP/CPM to process oil shales in Australia contingent upon SPP/CPM constructing and operating the ATP demonstration project.

AOSTRA's formal agreement with SPP/CPM ensures that the prime engineering of the ATP systems and construction of the key components of the processing plant will be conducted in Alberta by the Calgary firm UMATAC Industrial Processes, which has developed the ATP technology with AOSTRA over the past 13 years. The agreement also allows AOSTRA's participation in the performance testing of the demonstration plant and ownership of all new processing, mechanical, and scale-up technologies developed during the operations of this plant. The processing of oil shales is very similar to that of oil sands, hence this will provide AOSTRA with new improved technologies which can be incorporated into large ATP processing plants for Alberta oil sands applications.

4.6 ATP Application in the Treatment of Hydrocarbon-Bearing Soil Materials

The application of the ATP technology in this field has been commercialized. In 1988, AOSTRA granted the developers of the technology, UMATAC Industrial Processes of Alberta, a division of UMA Engineering Ltd., an exclusive license in North America for commercial application of the ATP in the field of treatment of hydrocarbon-bearing soil materials. The license agreement also allows UMATAC to grant sub-licenses for such purposes to third parties.

License royalties have been and will continue to be paid by UMATAC to AOSTRA for commercial processing of hydrocarbon-contaminated soil materials by UMATAC and all of its sub-licensees.

SoilTech Inc. of Porter, Indiana, a subsidiary of UMATAC, and Canonie Environmental Services Corp. of Porter, Indiana, were sub-licensed to commercially use the ATP technology for remediation of hydrocarbon-contaminated soil materials in the United States. There are many thousands of hydrocarbon-contaminated sites in the United States, 1100 of which have been identified as Superfund sites administered by the U.S. Environmental Protection Agency (EPA).

SoilTech purchased the first commercial ATP plant for soil remediation from UMATAC in 1988 for $4.5 million (Canadian). The 240-TPD transportable ATP plant was constructed by UMATAC in Alberta during 1989 and was successfully performance tested at AOSTRA's Calgary pilot plant site. The ATP plant was transported to Wide Beach near Buffalo N.Y. to clean up about 38,000 tons of oil-contaminated soils containing polychlorinated biphenyls (PCBs). To date about 20,000 tonnes of soil material have been treated. The ATP treatment process incorporates an EPA-developed technology to neutralize the PCBs within the processor. The AOSTRA Taciuk Process has been approved by the EPA for treatment of PCB- and oil-contaminated soils. Upon completion of the cleanup at Wide Beach, the 240-TPD ATP plant will be relocated to Waukegan harbor in Illinois for cleanup of similar materials.

The ATP plant at Wide Beach, NY is sited near the contaminated area. After treatment, soil passes up the conveyor at right for loading and hauling. Extracted hydrocarbons are collected to the left of the rotating cylindrical retort.

Taking part in the commissioning of the commercial ATP plant (from left), William Taciuk, William Yurko, Lee Richardson MP, the Hon. Rick Orman, and the Hon. Ralph Klein.

In 1989, UMATAC and ADS Engineering of Montreal formed a new Canadian company, ADSUMA Inc. ADSUMA is the first Canadian licensee of the ATP technology for cleaning up hydrocarbon-bearing soil materials. UMATAC and ADSUMA have prepared proposals for potential clients such as Alberta firms, major oil

companies and utility companies, and other provincial agencies for oil recovery from drilling muds, oil field production wastes, coal tar contaminated soils, harbor sites, and abandoned refinery and petrochemical plant sites.

Through the efforts of AOSTRA, much international interest has developed for using the ATP technology for hydrocarbon recovery from contaminated soils. These include contaminated oil fields in Russia, China, and the Persian Gulf area.

4.7 Anti-Water-Coning Technology (AWACT)

This technology was developed in conjunction with Alberta Energy Company (AEC) and tested in AEC's Suffield Heavy Oil Project (SHOP) in east-central Alberta. The purpose was to provide remedial treatment to wells which were producing more water and less heavy oil than is economically viable. The technology developed consists of injecting a hydrocarbon-based liquid followed by injection of natural gas in a watered-out well. This treatment tends to block off the water resulting in more oil production, and hence a longer well life and greater reservoir oil recovery.

The AWACT treatment program for AEC's South Jenner wells has been under way since late 1990. Oil production increases from the nine AEC wells treated thus far has been good.

Eight AWACT treatments have now been conducted outside the AEC SHOP area.

AWACT technology licensing agreements have been executed with Petro-Canada (Bellshill Lake), PanCanadian (North Bodo), and Koch Exploration (Chin Coulee). AOSTRA is participating in cost-shared field tests with Amoco, Suncor, Renaissance, and Maxon, who are utilizing the technology under license.

From left: K. Ronaghan, J.D. Scott, R.W. Luhning, AOSTRA; A.F. Kiernan, AEC; D.P. Komery, W.J. Yurko, B.S. Anderson, AOSTRA; W.L. Williamson, M. Fazil, Westcoast Petroleum Limited; W.R. Freeborn, AEC.

An in-house market survey of potential applications was conducted and a business development plan was prepared.

4.8 AOSTRA-Syncrude Study for Mining/Extraction Comparisons with UTF SAGD Technology

Because of the increased materials handling costs associated with increasing overburden thickness and greater distances between extraction plants and mining operations, the two commercial mining oil sands projects in Alberta are examining improved technologies to recover bitumen more efficiently.

One method of accessing deeper reserves is to use the Steam Assisted Gravity Drainage (SAGD) technology developed at AOSTRA's Underground Test Facility. This approach would enable access to the bitumen in the oil sands beneath the existing tailings ponds without having to relocate the sludge currently in the ponds, and would permit accessing other deeper reserves within the existing mining lease.

In 1990 AOSTRA and Syncrude started a study to evaluate the technical and economic viability of using the SAGD technology to recover bitumen from the deeper areas of the existing surface mining lease in the Athabasca oil sands. Recovery of bitumen from deposits beneath the existing tailings ponds is also being considered.

4.9 Comparative Economic Evaluation of In Situ and Mining Options for Commercial Oil Sands Development

It is known that certain technologies are more applicable to oil sands mining

leases and others to in situ bitumen reserves. Even within each of these two major categories, specific technologies need to be technically and economically analyzed for optimal application.

In order to provide AOSTRA with a comparison of the different applicable technologies, an in-house study has been initiated. The objective is to conduct an in-depth comparative analysis of the various in situ and enhanced oil recovery options, the Underground Test Facility, SAGD technology, the AOSTRA Taciuk Process technology, and the various other mining and extraction options for commercial development of oil sands leases.

4.10 Atomic Energy of Canada Study on Comparison of Fuel Sources for Commercial Development of Oil Sand Leases

Depending on the recovery process used, energy equivalent to 5% to 20% of the energy in a barrel of bitumen is required to produce a barrel of bitumen from oil sands. This represents an important demand on natural gas, a premium fuel for other uses. AOSTRA is therefore supporting investigations into the potential for utilizing nuclear energy to generate the steam required for oil sands processing. Alberta Public Utilities is also evaluating the use of nuclear energy to generate electrical power instead of fossil fuels such as natural gas and coal.

4.11 Technology Sales

The Technology Sales marketing group is responsible for the commercialization of AOSTRA research results which cover all the scientific and engineering fields related to advanced oil recovery technologies. Most of the work during the past year has involved activities related to the commercialization in the following areas:

- AOSTRA Taciuk Processor (ATP)
- Underground Test Facility (UTF)
- Technology Transfer Services
- Technical Report Sales
- Anti-Water-Coning Technology (AWACT)

AOSTRA Taciuk Processor (ATP)

Royalties continued to accrue from UMATAC regarding the 10-TPH ATP operating at Wide Beach, New York.

A 5-TPH mobile ATP unit is being built for AOSTRA. It will be ready in early 1992. The mobile ATP plant will be used for:

- Field demonstration of processing oil sands and oil shales
- Cleanup of hydrocarbon-contaminated sites
- Demonstration of processing rubber tires and municipal solid wastes

A business plan is being developed to define the most viable approaches to the ultimate full commercialization of the ATP technology.

Proposals for treatability testing for the ATP have been sent to several clients. AM-RE Managers, Inc. have agreed to pay for a program of testing oil shale samples. The first phase of the project feasibility assessment is an examination of a 50-lb oil shale sample. The cost of this batch testing program will be $10,000 to be paid by AM-RE.

Discussions regarding the treatment of heavy oil wastes, emulsions, and sludges with the ATP are under way with other companies.

Underground Test Facility (UTF)

The UTF is still accepting additional industry participants to earn an interest in the lease and the technology. It is also possible to acquire access to the technology without earning interest in the lease. Several tours have been conducted to promote the UTF. Also, information packages are sent out to potential licensees on request. The May 1990 issue of the CPA Review featured the UTF on the front cover.

An exchange of non-confidential information between Atomic Energy of Canada Limited's Underground Research Lab (URL) and the UTF was also organized.

Technology Transfer Services

- At least six papers related to technology transfer were completed for presentation at conferences on topics including the ATP, AWACT, UTF, and AOSTRA's technology transfer philosophy.
- AOSTRA participated in six trade shows as follows:
  - Oil Sands 90 Trade Show — Fort McMurray, June 21–22, 1990;
  - Energy City Show — Estevan, Saskatchewan, May 30–June 1, 1990;
  - American Association of Petroleum Geologists (AAPG) Annual Convention, San Francisco, June 3–6, 1990 "Oil Sands Key to Canada's Future Oil Supply" by J. Stevens.

- National Petroleum Show — Calgary, June 11–14, 1990;
- Industrial Trade Show and Hi-Tech Exhibition, Calgary, September 1990;
- Lloydminster Heavy Oil Show, Lloydminster, September 1990.

Technical Report Sales

- Idemitsu Kosan Co. Ltd of Tokyo, Japan purchased the "AOSTRA/ Industry Heavy Oil Upgrading Study" report (18 volumes — Acres-Davy McKee) and six supplementary volumes for $25,000. Value — $35,000.
- The GLISP injection and production data accumulated during the GLISP seismic monitoring program (1986–87 inclusive) will be traded to Japan Canada Oil Sands (JACOS) for the JACOS integrated geophysical study. Value in kind — $57,600.

Ultramicrobacteria (UMB) Technology Licensing

Through conference presentations and AOSTRA staff contacts, two licenses are in the process of being issued to utilize UMB technology in the applications listed below. One application of this technology will lead to increased oil recovery from borderline or shut-in wells.

- *Continental Amelioration Research Environmentalists (CARE) Int'l Ltd.* For non-petroleum application of AOSTRA-owned UMB technology in areas such as seepage prevention for dam sites, irrigation, sewage works, mine tailings ponds, and contaminated sites.
- *Chambers Engineering.* For commercial application as an anti-water-coning control method in oil field production.

5 ENGINEERING AND TECHNOLOGY DEVELOPMENT

5.1 Alpha-Cyclic Steam Analytical Model

Development of cyclic steam stimulation analytical models for vertically and horizontally fractured reservoirs by Alpha Engineering was completed. AOSTRA was one of six participants each contributing $6250 to the project.

5.2 Amoco High-Pressure Air Injection Experiments

AOSTRA and nine other participants are supporting a one-year project being conducted by Amoco Production Company studying the potential benefits of high-pressure air injection in light oil reservoirs. The project commenced in January 1991.

5.3 Amoco WAG Ratio Study

A multiclient laboratory core flood study, to develop a better understanding of the effect of water alternating gas (WAG) ratios on the initiation and propagation of viscous instabilities in oil wet cores at tertiary conditions was initiated by Amoco Production Company in January 1991. AOSTRA and seven other participants are funding the one-year project.

5.4 AOSTRA/Industry Thermal Well Pumping Committee

AOSTRA and industry formed a committee in 1989 to improve the life and performance of downhole pumps in thermal operations. A program was developed under which pressure drops across a number of standard sucker rod pump valves have been measured and the effects of plunger and barrel clearances have been studied. Up to 11 oil companies, three pump manufacturers, AOSTRA, and the Alberta Research Council have actively participated in this work.

5.5 Golder Associates Hydraulic Fracture Propagation Study

Golder Associates initiated a study in April 1990 to enhance the current understanding of how hydraulic fractures form and propagate within unconsolidated oil sand reservoirs. The study utilized a large-scale laboratory physical model to demonstrate the injected fluid paths as well as pressure and sand movement during the fracturing process. The results of eight fracture tests are being analyzed and a proposal for a second phase is being developed. AOSTRA, four industry participants, and CANMET supported the first year's program costing $160,000. AOSTRA's share of the cost was $40,000.

5.6 Maurer DEA-44-Horizontal Well Technology

Phase 1 of a large multiclient consortium formed to collect, evaluate and develop horizontal well drilling, completion and production technology was completed in November 1990. A

strong technical base for horizontal well technology, in the form of technical reports, case studies, and analytical models has been obtained from Phase I. Phase II of the project, to extend this technology further, particularly in the completion and operation of horizontal wells, was initiated in November 1990. The cost of AOSTRA's participation was $35,000 (U.S.) in Phase I and is $35,000 (U.S.) in Phase II.

5.7 Mobil Geomechanical Study

A joint AOSTRA-Mobil study was initiated in January 1989 to measure the compressibility and other geomechanical parameters and to study the acoustic behavior of heavy oil sands under thermally induced stresses. Seismic responses to heat and pressure observed on 3-D monitor and sonic monitor logs in the Cold Lake area are being used for calibration. AOSTRA's share of the total program is expected to be $87,000.

5.8 AOSTRA Peace River Task Force

A task force comprising AOSTRA and four industry participants established in May 1989 evaluated the development potential of the Peace River oil sands reserve area. It was concluded that reserve lands had sufficient potential to warrant additional seismic work and possibly delineation drilling. Additional work has been deferred pending more favorable economic conditions. Expenditures for this project totalled $56,000.

5.9 Petrolphysics Inc. Jet Drilling Feasibility Study

AOSTRA initiated a feasibility study into the current status and merits of the water jet drilling technique and directional guidance system in 1991. This study is expected to be completed in the fall of 1991 and cost $30,000.

5.10 Servipetrol Transient Pressure Analysis of Horizontal Wells

Transient pressure analysis techniques for horizontal wells were investigated jointly by AOSTRA and Servipetrol Ltd. beginning in August 1990. An IBM PC-based computer program to analyze horizontal well tests in anisotropic naturally fractured oil and gas reservoirs incorporating wellbore storage effects was developed during the fiscal year. AOSTRA's 50% share of the project was $23,150.

5.11 Shell Bitumen Conversion Project

A joint AOSTRA-Shell project to analyze the aquathermolysis effects with various metal ions on the reduction of viscosity of Peace River oils was initiated in 1990. This work involved autoclave tests conducted by the Alberta Sulphur Research Laboratory in Calgary and was a follow-up of earlier work in the University Access Program. AOSTRA's cost is expected to be $41,000.

5.12 Simons Consulting Services Anti-Water-Coning Project

An engineering design study conducted by Simons Consulting Services Ltd. in 1988 and 1989 indicated that a novel concept to reduce water coning effects in oil wells was feasible. The selection and acquisition of a well by the operator to field test the concept is in progress. AOSTRA expenditures to date total $154,000.

5.13 Simtech Oil Sands Fracturing Study

Development of geomechanical stress-strain finite element models for oil sands fracturing is actively supported and funded by AOSTRA, other industry participants, and Energy, Mines and Resources Canada (CANMET). The final phase of this project was initiated in April 1990 and has combined models developed to date into a comprehensive modelling system for oil sands engineering. These models are being validated with field data from the Cold Lake oil sands and have been coupled to CMG-STARS, SSI-THERM and SIMTECH-DRS reservoir simulators. AOSTRA's funding for this final phase is $9360.

5.14 Simtech Study of Flow Through Perforations

AOSTRA participated in a multiclient study of flow through perforations in perforated casing completions. A 3-D single-phase finite difference model was developed to analyze perforation stability and sand production. The model was tested with data from physical laboratory perforation tests. The project was completed in late 1990 at a cost to AOSTRA of $20,000.

5.15 TDC Study Foamflood Simulator Study

TDC Reservoir Engineering Services conducted an in-depth study of the mechanisms of foam formation and propagation to block high mobility reservoir intervals. A one-dimensional model for scoping purposes and a three-dimensional isothermal numerical simulator to predict foam flood performance were developed. The project was funded equally by AOSTRA and six industry participants

and was completed in December 1990. AOSTRA's cost was $30,000 (U.S.).

5.16 In Situ Engineering Support Program

This program, established in 1987, provides funding for in situ engineering studies aimed at developing an understanding of various new technologies and supporting efforts to develop technology and market field applications. Achievements in 1990/91 included:

- Geomechanics application relative to gas-steam additives, minifracture test interpretation, and development of a minifracture test procedures manual.
- Development of a recovery process concept for the Grosmont carbonate bitumen resource in consultation with industry and utilizing detailed geological assessments and preliminary reservoir engineering studies.
- Microbial plugging tests completed by the Petroleum Recovery Institute. The lack of significant field core plugging resulted in postponement of the field testing that had been contemplated.

Expenditures in this program totalled approximately $85,500 in the 1990/91 fiscal year.

5.17 In Situ Site Studies Program

Geological and other studies supporting AOSTRA projects and potential projects are funded by this program. Activities during 1990/91 included:

- AWACT treatment designs and technology development.
- Geological studies of the Grosmont 2 and Grosmont 3 reservoirs.
- Petrophysical analyses and geological mapping of the Kearl Lake area of the Athabasca McMurray deposit.
- Wettability testing on AOSTRA UTF core.

Expenditures during the 1990/91 fiscal year were approximately $81,400.

5.18 In Situ Strategic Enhanced Recovery Program

This program provides support to enhanced oil recovery technology development. Activities during 1990/91 included:

- Assessment of the Retlaw immiscible CO_2 project.
- Development of a computer program to infer phase behavior from laboratory data.
- Engineering and economic feasibility studies of in situ gasification of depleted or low quality oil and bitumen reservoirs.
- Assessment of non-Newtonian effects on heavy oil production.

Expenditures during the 1990/91 fiscal year were approximately $110,300.

6 PRODUCED WATER RECYCLING PROGRAM

Since the late 1970s, AOSTRA has been actively involved in research dealing with the water which is co-produced with bitumen and heavy oil from in situ recovery operations.

Because of a limited supply of fresh water, it is desirable to recycle any water that may be recovered, rather than dispose of it completely as production waste. The recycling of produced water to meet steam generation requirements offers two significant environmental advantages: it reduces the consumption of fresh water resources, and it reduces the volume of wastewater requiring deep well disposal.

Produced water contains several impurities which must be removed if it is to be re-used as feed to a steam generator. In addition, the quality of the water produced with the heavy oil at an in situ recovery operation varies widely from one geological formation to another within Alberta.

AOSTRA's involvement in the area of produced water treatment is crucial to advancing the state of knowledge on this important issue and developing technologies and methods which can be commercialized.

6.1 AOSTRA/Environment Canada/Industry–Lindbergh Area Produced Water Treatment Project

In order to treat the produced water in the Lindbergh area for reuse as feed water for steam generation, it is important to reduce the total dissolved solids (TDS). TDS can be reduced in processes such as electrodialysis, reverse osmosis, vapor compression evaporation, and freeze desalination. Many of these technologies are currently not economically feasible.

In 1986, AOSTRA, Environment Canada, Amoco Canada Petroleum Company Ltd., Dome Petroleum Limited, Murphy Oil Company Ltd., PanCanadian Petroleum Limited, and Westmin Resources Limited initiated

the first phase of a project to test treatment processes for reducing TDS in produced waters.

In Phase I of this project, the efficiency and operating characteristics of a vapor compression evaporator (VCE) for TDS reduction were tested. Pilot testing of the VCE at Murphy's Lindbergh Thermal Project commenced in 1987 and was completed in 1988. Results of the pilot test demonstrated that TDS reduction by evaporation is technically achievable. However, pretreatment of the VCE feed would be necessary to stabilize characteristics of the water. This rendered the treatment more expensive than originally anticipated.

The total project cost of Phase I was $875,000 with AOSTRA's share being $375,000. The technical reports for Phase I have been listed in AOSTRA's Catalogue of Technology and Services (1990/91 price list) at a cost of $36,000.

Based on the costs estimated for vapor compression evaporation developed in the Phase I report, as well as preliminary cost estimates for electrodialysis developed by Environment Canada, a Phase II program was proposed to assess the economic feasibility of using membrane technology. Although the VCE process evaluated in Phase I was technically the most advanced of all the TDS reduction technologies, the fact that pretreatment was considered necessary suggested that electrodialysis, while not proven to the same degree as VCE, may offer potential cost advantages. Consequently, the participants approved the second phase of the project to test electrodialysis as a process for TDS reduction.

The cost of Part 1 of Phase II was $188,000 with AOSTRA's share being 50% or $94,000. The cost of Part 2 of Phase II is projected to be $462,000, with AOSTRA's share being $231,000. The total Phase II costs to AOSTRA will be $325,000.

Based on the results of Part 1, the management committee has elected to proceed to Part 2 of Phase II. The proposed field pilot work under Part 2 will be conducted at the Amoco Elk Point site. The first part of the work involves the construction of a pilot-scale, continuous-flow 3.5 L/m electrodialysis (E/D) unit. The E/D unit is being custom made for high-temperature produced water application. Produced water feed to the E/D unit will be pretreated by passing it through a microfiltration membrane (selected from Part 1 above) for removal of oil and suspended solids.

The second part of the work will involve pilot testing of the electrodialysis process in the field. The field work is expected to begin by mid-summer of 1991. A field site is currently being finalized by Environment Canada for installation of pilot test facilities. Site selection has been hampered by the recent downturn in heavy oil prices, resulting in decreased steaming/production activity in the area.

6.2 AOSTRA/CANMET/ Monenco Thermal Lime Softening (TLS) Process Development

Presently, the only commercially available technologies for the reduction of hardness and silica in produced waters are the hot lime and thermal softening processes, such as those being used by Esso Resources at Cold Lake. The disadvantages of hot lime softening are its relatively high capital costs and the production of large quantities of lime sludge requiring disposal. Depending on the influent silica concentration, neither process may adequately reduce silica content to acceptable boiler feedwater concentration. In addition, these systems generally require a fairly intensive maintenance schedule.

In 1988, AOSTRA joined with Monenco Consultants Limited, Energy, Mines and Resources Canada (CANMET), and Supply and Services Canada to investigate and test a thermal lime softening process, which incorporated magnesium sulphate addition for silica removal (in a single reactor). Phase I of the project involved bench-scale testing of the process in batch equipment. The results indicated that the process should be able to reduce silica and hardness to boiler feed specifications within 10–30 minutes. Consequently, it was decided that there was sufficient evidence to support testing the technology for a continuous flow at pilot scale. The cost of Phase I was $115,254 (AOSTRA's share being $57,627); the final report was received in June of 1989.

Phase II is to consist of the engineering, construction, and operation of a 6-L/min continuous pilot plant. The objectives of Phase II are basically to confirm the TLS technology at the continuous pilot scale and to gain operating experience for possible incorporation into a commercial-scale design (Phase III). The cost of Phase II is projected to be $600,000. This cost is to be shared equally between AOSTRA and CANMET ($300,000 each), with Monenco conducting the work.

The initiation of the Phase II work has been delayed pending completion of negotiation of an appropriate project agreement among AOSTRA, CANMET, and Monenco.

7 SURFACE MINING/ EXTRACTION PROGRAM

7.1 AOSTRA Taciuk Direct Thermal Processor

The AOSTRA Taciuk Process (ATP) is a thermal retorting or pyrolysis process developed for the simultaneous extraction and primary upgrading of bitumen from mined oil sands. Process operations occur in a single horizontal rotating vessel which is subdivided into four distinct functional zones. The products from the processor are cracked oil distillates, oil-free dry tailings, off-gas, and process waters.

The process, which is owned by AOSTRA, has been developed since 1977 in collaboration with UMATAC Industrial Processes, a division of UMA Engineering Ltd.

Approximately $20 million has been spent in developing the process at AOSTRA's 105-TPD continuous flow pilot in Calgary. Approximately 15,000 tonnes of oil sands and other materials have been tested in the pilot. This work has successfully demonstrated that the ATP is a technically feasible and cost-effective method for the extraction of bitumen from mined oil sands.

The ability of the ATP to process a wide variety of hydrocarbon-bearing feed-stocks has led to the parallel development of the process for the treatment of oily wastes and the recovery of liquid hydrocarbons from oil shales.

Specific tests on 500 tonnes of various waste materials resulted in AOSTRA granting UMATAC an exclusive license to use the AOSTRA Taciuk Process for the treatment of hydrocarbon-bearing wastes. Construction of the first commercial ATP plant for oily waste remediation was completed in 1989.

The AOSTRA Taciuk Process has been shown to be an effective method for recovery of liquid hydrocarbons from oil shales. This development has led to the detailed engineering phase of a 6000-TPD ATP demonstration plant in Queensland, Australia. Southern Pacific Petroleum of Sydney Australia, under an agreement with AOSTRA, is pursuing this development.

The AOSTRA Taciuk Process has the potential to treat other hydrocarbon-bearing and organic solids such as municipal and industrial wastes, rubber and plastic products.

To investigate this potential, a jointly funded project was initiated involving AOSTRA, the Alberta Research Council, the Alberta Environmental Centre, and Alberta Technology Research and Telecommunications with the aim of testing municipal solid waste treatment with the AOSTRA Taciuk Process to achieve volume reduction. The first phase of this program involved the processing of a 50-tonne sample of compacted, extruded municipal waste in the continuous flow pilot plant in Calgary. This was followed by batch testing to assess in greater detail pyrolysis and combustion of the resultant char. Based on the results of analytical work currently under way, a decision will be made on further development.

Development of the AOSTRA Taciuk Process is continuing, with focus on metallurgical and environmental performance. One specific program initiated is the piloting of a new flue gas desulphurization system. A pilot has been constructed and will be tested in the coming year.

Continuing interest in the AOSTRA Taciuk Process has given rise to numerous test programs on candidate feeds from around the world, further emphasizing the growing commercial potential for the AOSTRA Taciuk Process.

7.2 OSLO (Other Six Leases Operation) Dredge Mining and Cold Water Extraction Development Project

The OSLO dredge mining and cold water extraction process is a major new development in the mining and extraction of oil sands which has the potential to significantly reduce the overall cost of bitumen production from mined oil sands. The process consists of mining the oil sands with dredges and slurrying the oil sands to the cold water extraction plant for recovery of the bitumen. This process has the additional benefit of producing tailings which have more favorable settling characteristics for solids reclamation and water recycle than those generated in the hot water extraction process.

Four years of research and development have been completed, with the costs shared on a 50/50 basis between AOSTRA and OSLO.

The first three years (1987–1989) of piloting and laboratory testing concentrated primarily on determining the bitumen, air, and chemical addition rates required for the separation process, evaluation of settling and layering characteristics of the tailings, development of a feasible process for cleaning the bitumen froth, and optimization of the process flow and equipment. Field piloting of the process was conducted on Lease 41.

The fourth year of the program (January 1, 1990 to October 31, 1991) focused on finalizing the design criteria for an 800-TPH demonstration plant to test the process on a semicommercial scale. The $8.2 million, 1990 program has been completed. The major highlights of this program include: construction of a pilot and successful demonstration of a new high-temperature, high-pressure froth cleaning technology, demonstration that fine tailings can be layered both under controlled laboratory conditions and on the Lease-41 pilot, and completion of a design basis and cost estimate for the 800-TPH demonstration plant including certain preliminary regulatory work.

Due to budget constraints, AOSTRA has notified the OSLO consortium that it will not participate in the 800-TPH demonstration project at this time.

7.3 OSLO (Other Six Leases Operation) Borehole Mining and Cold Water Extraction Process

OSLO leases contain approximately 17 billion barrels of bitumen at depths ranging between 100 and 300 metres. At these depths, conventional surface mining is uneconomical and therefore other low-cost methods of accessing the oil sand must be developed. One such method is currently being developed by the OSLO consortium. The technique involves drilling a borehole to the oil sands and hydraulically mining by means of a high-pressure water jet mounted on an extendable arm. This arm would enable the mining of large subsurface cavities. Early in the development, it was determined that this mining approach would be compatible with the OSLO cold water extraction process which had been developed in conjunction with dredge mining.

AOSTRA has participated in three years of development with OSLO. The first year of the program involved preliminary jetting tests in the field and laboratory. Year two involved the development of a quarter-scale extendable arm, the purchase of a borehole mining system, geotechnical modelling, and feasibility screening studies.

The 1990 program (Year 3) has been completed. The budget for this program was $1.5 million with AOSTRA's share being 50%. The program consisted of delineation of the reserve and geotechnical evaluation of the Lease-41 test site, restoration of the mining and pump trailers of the borehole mining system to full operational status, testing the extendable quarter-scale arm in a slurry environment at the Esso Resources Canada Limited test facility in Calgary, field and laboratory geotechnical analysis, and completion of three underground test cavities on Lease 41 at 10- and 20-metre depths.

The results of the 1990 program were sufficiently encouraging to justify proceeding with the next phase of the program. This next phase involves preparatory work which would lead to a demonstration pilot in 1993. AOSTRA has agreed in principle to limited participation in this next phase.

7.4 Solvent Extraction Sand Agglomeration (SESA) Process

AOSTRA, the National Research Council (NRC), and Terra Energy Ltd. have completed a project to prepare the engineering design and cost estimates for a demonstration plant to test the SESA Process for the extraction of bitumen from mined Athabasca oil sands.

Terra Energy Ltd. has been granted a license by Canadian Patents and Development Limited to develop and operate a SESA demonstration plant. The SESA Process has been developed and piloted on a laboratory scale by NRC.

The SESA Process involves contacting mined oil sands with carefully controlled small amounts of water and naphtha solvent in a rotating drum. The naphtha solvent extracts the bitumen while the water facilitates the agglomeration of the fine clay minerals with the sand particles. In a series of solids-liquid separating steps, bitumen diluted with solvent naphtha and a tailings of agglomerated solids wetted with the naphtha solvent are produced. The solvent is recovered from the bitumen by conventional refinery distillation and from the tailings by evaporation. The recovered solvent is recycled in the process. The dried agglomerates can be transported by trucks or conveyors to the mined-out pit for disposal.

The project was completed at a cost of $1.0 million, funded on a 50/50 basis by AOSTRA and NRC. The work completed includes detailed engineering and cost estimate for the construction and operation of a 10-TPH demonstration plant to be located at a site near Fort McMurray and economic comparison studies comparing both a 30,000 BPCD and a 75,000 BPCD mining project incorporating the SESA Process with similar sized plants utilizing the existing hot water extraction process. The economic studies showed an economic advantage for the SESA Process, particularly when processing lower grade oil sands.

Although supportive of the demonstration plant proposal, AOSTRA has notified Terra Energy

Ltd. that due to budget restrictions, it will not participate in the 10-TPH demonstration pilot at this time.

7.5 Canadian Oil Shale, Burning Rock Oil Co. Ltd.

AOSTRA and Burning Rock Oil Co. Ltd. are currently evaluating the feasibility of using the AOSTRA Taciuk Process for extracting oil from Saskatchewan oil shale.

Burning Rock Oil has identified an area within their oil shale permits which may contain oil shale feed with sufficient kerogen content to permit economic recovery of shale oil using the AOSTRA Taciuk Process.

Extensive testing on oil shales has demonstrated the AOSTRA Taciuk Process to be an effective way to extract the oil from oil shale. Such a project, if economically viable, would provide an opportunity to demonstrate the process for oil shale applications.

AOSTRA is participating in Phase I of a proposed two-phase project. The cost of Phase I is $60,000 which is being funded 100% by AOSTRA.

The work involves drilling five core holes for sample acquisition, batch testing at the AOSTRA Taciuk Process pilot plant, preliminary engineering, cost estimates, and economic analysis.

Progress to date includes the completion of the five core holes, slabbing and logging of the cores, and identification of the sections to be batch tested.

7.6 Syncrude Disposal of Tailings Pond Sludge in Mined Overburden Dumps

AOSTRA and Syncrude Canada Ltd have completed a project to evaluate a concept by which tailings ponds sludge would be mixed with the Clearwater Formation material of the overburden to form stable overburden dumps. Such a technique of dewatering the sludge by adsorption of water into the Clearwater clay shales stable overburden dumps would provide a dry landscape option for disposing of the tailings sludge.

The program was executed in two phases. Phase I involved laboratory and field experiments in order to determine geotechnical criteria. Phase II involved full-scale testing under commercial conditions with 170-ton trucks, dozers, and support equipment to transport and mix the sludge and overburden. The scope of the study was extended, at no cost to AOSTRA, to include dragline casting of the overburden into the sludge to simulate an overburden conveyor spreader.

The results of this program were sufficiently encouraging to allow Syncrude Canada Ltd to include this sludge disposal method in their long-term plans as a dry landscape option.

8 UPGRADING PROGRAM

The major emphasis for AOSTRA in the heavy oil upgrading area has been the demonstration of high-conversion hydrocracking processes. Major process demonstration programs have been completed in previous years for a number of upgrading processes in collaboration with the respective process developers including:

- Veba Combi Cracking process in 1985 and 1987. Developer, Veba Oel Aktiengesellschaft.
- High Conversion H-Oil process in 1987. Developer, Hydrocarbon Research, Inc.
- CANMET Hydrocracking process in 1989/90. Developers, Petro-Canada and Lavalin, Inc.

Process demonstration activities were continued in 1990 leading to completion of a pilot test of ABB Lummus Crest, Inc.'s LC Fining process incorporating a coke precursor removal system.

Another series of projects in 1990 was concerned with the coprocessing of coal and heavy oil mixtures in hydrocracking processes. AOSTRA was involved in the second phase of an AOSTRA/Industry study of opportunities for coprocessing in Alberta and in a test of a counterflow hydrocracking reactor designed by Canadian Energy Developments Inc.

8.1 LC Fining Test Program

AOSTRA has funded half the cost of a $2.23 million (U.S.) project to demonstrate high-conversion operation of ABB Lummus Crest Inc.'s LC Fining process through use of a coke precursor removal (CPR) step. The demonstration was carried out using Alberta feedstocks. The LC Fining process is being used successfully in commercial operations at low conversion at Syncrude Canada Ltd's Mildred Lake plant and in conventional crude oil refineries.

The CPR step permits the unconverted vacuum residue component in the reactor product to be recycled to the reactor with reduced risk of reactor fouling due to coke formation.

The test work has been successfully completed. The removal of coke

precursors from the pitch recycle stream, as measured by the Shell Hot Filtration Test (SHFT), permitted operation at residue conversion rates ranging between 88% and 97% by volume, on three test feedstocks: Cold Lake vacuum bottoms, Peace River asphalt, and Athabasca bitumen. Correspondingly high results were achieved for demetalization, desulphurization, and Conradson carbon residue (CCR) removal. Hydrotreating tests were undertaken on the hydrocracked distillate products, combined with straight-run distillates, to determine the process conditions required to meet specifications for high-quality synthetic crude oil.

The test data have been used to prepare a conceptual design and cost estimates for a commercial-scale upgrader using high-conversion LC Fining with CPR and integrated hydrotreating. This design and cost information will be used by AOSTRA to develop a comparative economic evaluation of upgrading process options.

8.2 Coal–Heavy Oil Coprocessing Study

In 1990 AOSTRA initiated Phase II of a study to examine the benefits of adding coal as a supplemental feedstock to heavy oil upgrading. The results of Phase I indicated that coprocessing was technically feasible and economically attractive compared to heavy oil upgrading when oil prices are high. The low cost of coal in Alberta can offset the higher cost of heavy oil or bitumen to produce valuable synthetic crude oil.

The objective of Phase II is to define and explore the opportunities that could lead to a pioneering commercial co-processing venture in Alberta. Twelve companies are participating with AOSTRA and paying half the Phase II costs which are budgeted at $200,000. The balance of the Phase II costs are shared equally by AOSTRA and the Alberta Office of Coal Research and Technology. The study reviews the strategic factors which affect project decisions including location, marketing, technology, and environment.

In Alberta, the raw materials (heavy oil, coal, and natural gas) required for coprocessing are abundant. The infra-structure exists to transport feedstocks and market products. Integration of coprocessing operations with coal mines, power plants, or refineries may reduce the costs or improve the benefits of initial coprocessing ventures.

Engineering studies are now under way with Monenco Consultants Limited, Kilborn Engineering Alberta Ltd., and Purvin and Gertz Inc. as independent prime contractors. The project will be completed in 1991.

8.3 Counterflow Reactor Test

Canadian Energy Development Inc. (CED) has been testing coal–heavy oil coprocessing technology based on a counterflow hydrocracking reactor. In most hydrocracking reactors the coal, oil, and hydrogen feeds enter the bottom of a bubble/slurry phase reactor and exit at the top. In Germany, GfK, a partner of CED, tested an alternative system utilizing a counterflow reactor in which the coal/oil slurry feed enters at the top of the reactor countercurrent to the hydrogen flow which enters at the bottom.

AOSTRA and the Alberta Office of Coal Research and Technology funded half the cost of a $1.19 million test program to demonstrate the counterflow reactor technology in a pilot plant using Alberta feedstocks. A series of tests has been successfully completed using the CED pilot plant at the Alberta Research Council's High Pressure Test Facility at Nisku. Most of the expected benefits such as reduced feed preheating, lower gas rates, and improved operability have been observed. A series of tests to hydrotreat counterflow reactor products to high-quality synthetic crude oil are also under way at the Alberta Research Council.

8.4 Coking Characteristics of Hydrocracked Pitch Recycle

A process configuration in which low-conversion hydrocracking of heavy oil or bitumen is followed by coking of the unconverted hydrocracked pitch residue is an alternative to high-conversion hydrocracking, and is the basis for a number of commercial upgraders. This combination of processes is exemplified by Syncrude Canada Ltd's LC Finer combined with Fluid Coking, Husky Oil Ltd.'s Biprovincial Upgrader which combines the H-Oil process with delayed coking, and NewGrade Energy Inc.'s atmospheric residue desulphurization plant in combination with delayed coking.

AOSTRA is one of the participants together with Husky Oil Ltd. and NewGrade Energy Inc., in a multiclient project being carried out by the Saskatchewan Research Council to determine the coking characteristics of hydrocracked pitch residue at various operating conditions and to evaluate possible methods for controlling the coking rate. The test work is complete. The total cost of the project is estimated at $122,000 with AOSTRA's contribution being $20,000.

8.5 CO_2 Balances in Upgrading

AOSTRA has initiated a study to develop carbon dioxide and hydrogen balances for a range of upgrading scenarios with particular reference to hydrogen generation alternatives. The results will be analyzed to examine appropriate routes by which carbon dioxide emissions may be minimized. The study is being carried out by RTM Engineering Ltd. at a cost to AOSTRA of $49,000.

9 ENVIRONMENTAL ACTIVITIES

The advancement of relevant environmental research, as well as the compilation, assessment, and dissemination of pertinent technical information are part of the mandate of AOSTRA. Many of AOSTRA's projects deal with the development of technologies which offer potential for environmental benefits, if successfully applied commercially, even though the environmental benefits may have been supplemental to the broader goals of enhanced economics, resource utilization, and removal of technical roadblocks to resource development. However, AOSTRA has begun to take a more proactive approach in the environmental area, by supporting projects which deal specifically with current environmental issues. AOSTRA has and continues to participate in projects which address:

- new processes for the extraction of bitumen from mined oil sands such as thermal retorting and solvent extraction processes, which generate dry or damp tailings and thus eliminate or reduce the need for tailings ponds;
- high-conversion bitumen upgrading processes which reduce the production of upgrader residues that are normally disposed of or stockpiled as waste byproducts;
- produced water treatment processes which permit water for steam generation for in situ recovery to be recycled thereby ensuring supplies of boiler feedwater while at the same time reducing the demand for fresh water and the amount of contaminated water that is sent to deep disposal wells;
- the development of the AOSTRA Underground Test Facility to demonstrate the viability of shaft and tunnel access to bitumen reservoirs that are too deep for surface mining and too shallow for conventional in situ techniques involving high-pressure steam injection. Surface disturbance is minimized as a consequence of the underground access to the reservoir;
- research initiatives which address relevant environmental issues such as tailings waste disposal, oily produced solids cleanup, reducing the toxicity of oil sands products, and the reduction of gaseous emissions such as SO_2, CO_2, and NO_x.

9.1 AOSTRA/Government/ Industry — Sludge Fundamentals Consortium

Currently, there are millions of cubic metres of sludge in the tailings ponds of the oil sands mining plants located in northeast Alberta. The cleanup and reduction in the size of the tailings ponds resulting from use of the hot water process is a major environmental objective. The occurrence of the sludge layer in the tailings pond contributes to the ever increasing volumes of material which must be retained in the tailings ponds (since the fine solids settle very slowly or not at all). Methods are needed to dispose of this waste in an environmentally acceptable manner.

The private sector companies presently engaged in commercial mined oil sands projects, as well as AOSTRA and many institutional research organizations, have each been searching for solutions to the tailings sludge problem independently for many years.

In 1989, a consortium of research organizations, private sector companies, and government agencies was assembled to pool their scientific expertise in an effort to attack the sludge problem in a coordinated research program. In addition to AOSTRA, the members of the Sludge Fundamentals Consortium are the Alberta Department of Energy, the Alberta Research Council, Energy, Mines and Resources, Canada (CANMET), the National Research Council, Environment Canada, Suncor Inc., and Syncrude Canada Ltd.

The research projects initiated by the consortium are focusing on the development of a better understanding of the physical, colloidal, chemical, and organic properties of the oil sands sludge which are thought to inhibit settling of suspended solids, and to explore methods by which these properties may be altered to promote solids settling.

Approximately $1.2 million of in-house research costs were contributed to the consortium as work-in-kind by member organizations in the first year of this three-year program. In addition, AOSTRA, Alberta Energy and CANMET contributed cash to a total value of $500,000 (AOSTRA's contribution was $200,000) in Year 1,

of which only $248,671 was utilized because of the late start in getting research underway. Consequently, the Year 1 value of the consortium effort was about $1.5 million.

The cash contributions are used to purchase additional research work from specific member organizations and to contract third-party research from non-member groups such as universities and consultants.

The first year of work has been completed and the research reports have been compiled into a final year-end report. This research addressed a number of specific issues, including:

- confirmation of the very strong role that the "ultrafine" particles (<200 nm) play in the stability of the sludge;
- formulation of a theory on sludge structure. Cardhouse and chain-like structures are being postulated for the mature sludge, on the basis of scanning electron microscopy;
- focus on the measurement of the electrophoretic properties of mineral fractions from sludge;
- extractability of ionic species from sludge and their concentrations in relation to the solubility products of mineral species;
- work on the effect of caustic on sludge volume which indicated that the chemistry of the water used in the extraction process can greatly effect the nature of the sludge formed;
- the role of organics and specific mineral components in sludge formation and subsequent diagenesis.

The program is in its second year. A further cash contribution of $500,000 has been committed to the Year 2 research by AOSTRA, Alberta Energy, and CANMET, with AOSTRA's contribution being $200,000. The Year 2 value of both in-kind research and third-party contract work is estimated at $2.5 million. The Technical Committee has identified specific focus areas of research including: ultrafine particles, clay/mineral interactions, clay-organic interactions, microbial activity, water chemistry/geochemical modelling, sludge treatment and sampling, and sample preparation. Subcommittees have been delegated to coordinate the research within each of these areas of research.

9.2 AOSTRA/CPA/SASK-ALTA Waste Disposal Co-op — "Evaluation of New Technologies for Cleanup of Produced Oily Solids"

Completed in 1990 was a cooperative effort among AOSTRA, the member companies of the Canadian Petroleum Association (CPA), and the Sask-Alta Waste Disposal Cooperative, to assess the state-of-the-art technologies available for the cleanup of produced oily solids (especially oily produced sand). The project was conducted under the auspices of the CPA; consequently it involved all of the relevant industry companies, and provided an opportunity for all to benefit from the results.

Under the direction of a Project Steering Committee an engineering consultant, Monenco Consultants Ltd., was responsible for assembling information on candidate processes and for the preparation of the comparative technical/cost evaluations and final report.

The objective of the project was not to identify a particular technology as being the preferred choice for cleanup of oily produced solids, but rather to identify *new* technologies which demonstrate a high degree of potential for cleanup of heavy oil produced solids and for which, little information currently exists. Three technologies identified by a Kepner-Tregoe (KT) logical decision analysis were selected for more detailed assessment by the consultant and then presented to the Project Steering Committee for final consideration. One or two of these technologies will then be selected by the committee for field testing in Phase II of the project.

A total of $60,000 was allocated for Phase I of the project. AOSTRA's share was $30,000 with CPA contributing $20,000 and Sask-Alta. Waste Disposal Co-op contributing $10,000.

The final report was received in July of 1990. The three new technologies selected by KT analysis as having the most potential, but requiring further field assessment, included: Alberta Solids Treatment Company's hot water extraction process; Pacific Environment Systems' Fluid Bed Combustor; and Halliburton Services' produced sand re-injection (hydraulic fracturing for deep well disposal).

The AOSTRA Taciuk Processor was assessed and highly ranked; however, it was not in the group of selected processes. Special consideration was given to this fact subsequent to the KT analysis and it was felt that the ATP is a proven technology with a well established data base. Consequently, it was recommended that the ATP be used as the base process technology for the Phase II assessment program, if initiated.

Phase II is to be a pilot-scale field assessment of the recommended technologies from Phase I. However, specific work scope terms and costs are

still to be worked out. In addition, interested funding agencies are still to be identified.

9.3 AOSTRA/Government/ Industry — CO_2 Disposal Study

Emissions of carbon dioxide (CO_2) principally as a result of the combustion of fossil fuels, are acknowledged to be one of the major contributors to the atmospheric accumulations of greenhouse gases. It is generally recognized that there is no short-term alternative to the use of fossil fuels in our society. However, it may be feasible to collect and dispose of large accumulations of CO_2 in subterranean geological formations, or in certain hydrocarbon-bearing reservoirs in which CO_2 injection could enhance the recovery of liquid hydrocarbons.

The CO_2 Disposal Project was originally conceived as a result of an application submitted to AOSTRA by the oil industry to carry out a study to examine the methods and costs for the capture, purification, transportation, and disposal of CO_2, with emphasis on the benefits arising from its use for purposes of enhanced oil recovery. During the evaluation of the submission, it became clear that such an initiative was of interest to a number of parties, including the major oil companies, power companies, support industries, and specific departments of both the provincial (Alberta and Saskatchewan) and federal governments. Consequently, participation in the study was opened to a broad cross section of industrial companies and government agencies and departments.

Twenty-four participants, from industry and government, with AOSTRA acting as the operator, have completed Phase I, the scoping phase of this study, aimed at determining the technical and economic feasibility of reducing the rate of growth of CO_2 emissions by collecting CO_2 from major sources and disposing of the collected gases where offsetting benefits may be obtained.

Phase I focused on enhanced oil recovery as the best alternative for disposal of 50,000 tonnes per day of CO_2 captured in Alberta and Saskatchewan. Phase I was notable for a very high level of participant involvement, and was also successful for this reason.

Phase I was completed in April 1991 at a cost of approximately $30,000 or 60% of budget. Fifty percent of Phase I costs were paid by AOSTRA and the balance shared equally by the other participants. The overall objective of Phase I was to work out the detailed work scope of the study to be conducted in Phase II. Specific objectives of Phase I included:

- identification of major CO_2 sources;
- selection of specific technologies for detailed review in recovery, purification and distribution;
- definition and selection of candidate disposal options such as EOR reservoirs;
- consideration and definition of alternative disposal options;
- establishment of the budget and schedule for Phase II;
- selection of the contractor(s) who will conduct Phase II; and
- development of the Phase II agreement.

Phase II will examine four different types of emission sources. Reflecting their relative contribution, two coal-based electrical generating stations have been included: Boundary Dam in Saskatchewan and Sundance in Alberta. The most common stationary source of CO_2 in Western Canada is natural gas combustion. Two sources of natural gas emissions will be examined: a sour natural gas processing plant, and a typical high-quality source, a hydrogen plant vent.

A range of commercial or demonstrated processes will be screened to establish cost-effective reliable technology for gas conditioning, CO_2 capture, and purification. Costs will be determined for a dedicated pipeline network to distribute CO_2. These systems will be located and designed as part of the work scope.

A variety of reservoirs and reservoir types containing both light and heavy oil are to be screened and data collected. Simulations will be run on selected typical pools to predict incremental oil recovery and CO_2 utilization. The plan is to use a depleted natural gas reservoir to balance supply and demand.

The work scope for Phase II is broken down into three work packages:

(i) facilities

(ii) subsurface

(iii) economics

The budget for Phase II is $600,000. Start of Phase II is planned for June 1991 with completion scheduled for June 1992.

AOSTRA and other Alberta Government agencies will provide a maximum of $300,000 for Phase II. The remaining $300,000 will be shared equally by a minimum of 10 participants from industry and other governments.

9.4 In-House Environmental Initiatives

Environmental Audit Program

Environmental audits are conducted to identify and assess situations which may fail to meet regulatory requirements or corporate standards, or which may represent unacceptable risks to the corporation, community, or public.

To date AOSTRA has undertaken environmental audits of five facilities: Amoco GLISP, Norcen Bodo, Husky Kearl Lake, Bow Valley Industries, and the Underground Test Facility. Two of these audits are complete (Norcen Bodo and Husky Kearl Lake) and final copies of the reports have been issued to all parties involved. The remaining three are being rewritten in a slightly revised format. Amoco GLISP has been completed under this new format and will serve as the model for the remaining two.

Subsequent audits will be conducted according to a more formal and concise framework. The main thrust of this initiative is that the audits be used as an environmental management tool, and not just an examination of environmental compliance.

A properly conducted auditing program of projects in which AOSTRA is either the operator or a participant will give effect to AOSTRA's environmental commitment in the following ways:

- AOSTRA would ensure that it has addressed the environmental, health, and safety aspects of facilities in terms of it's own responsibilities as a public crown corporation as well as a partner (owner) in the project.
- An assessment of the environmental situation if the process were to go to commercial scale (i.e., commercial-scale level of waste emissions and other problems/issues not encountered at pilot scale).
- A catalogue of all inputs/outputs on an operational basis for the pilot as well as a potential commercial unit.
- The audits may identify specific research and development opportunities for technologies with potential for commercial application.

An environmental audit of AOSTRA's AOSTRA Taciuk Process pilot facilities is currently under way. A final report is expected by the end of July 1991.

Associations:

AOSTRA continues to participate on the Canadian Heavy Oil Association (CHOA) Environmental Committee and has played an active role in the organization of committee meetings, luncheon seminars, and quarterly meetings.

AOSTRA is an Associate member of the CPA (Canadian Petroleum Association) and actively participates on the Environmental Research Advisory Council (ERAC) of the CPA.

AOSTRA has recently become a member of the Alberta Special Waste Management Association. This membership allows AOSTRA to maintain a close link with current events in the waste management area, as well as providing another route for presenting the ATP as a waste processing technology alternative.

10 UNIVERSITY PROGRAMS

10.1 Lectureships

The AOSTRA Lectureship Program was introduced in 1988. The program is intended to fund experts from Canada and abroad to travel to Alberta to present seminars or courses to industry and to the research community in areas relevant to AOSTRA's mandate. It provides a means of teaching new skills needed to make Alberta's oil producing industry more competitive.

In a survey, it was determined in 1989 and again in 1990 that the province needed to develop expertise in the science of colloids and surfaces. Colloids such as the fine dispersions of clay and oil found in produced fluids and in tailings ponds are difficult and expensive to handle. Consequently, in May 1990, Professor P. Somasundaran, Director of the Langmuir Center for Colloids and Interfaces, Columbia University, and Professor Darsh T. Wasan, V.P. for Research and Technology, Illinois Institute of Technology gave 32 hours of advanced lectures on the chemistry of colloids. These lectures were directed to 40 experts invited from university, industry, and government. AOSTRA, CANMET, and Syncrude Canada Ltd. co-organized the lectures and provided financial support.

At a second workshop in March 1990, Professors J. Grace and L.S. Fan, noted experts from the University of British Columbia and Ohio State University respectively, gave 24 hours of lectures on hydrocracking hydrodynamics to 40 of Alberta's leading scientists and engineers working on refining and upgrading of bitumen. Syncrude Canada Ltd, CANMET, and AOSTRA co-organized these lectures and provided financial support.

10.2 Graduate Scholarships and Fellowships

Post-graduate scholarships and fellowships have been made available for the past 12 years to graduate and post-doctoral students doing oil sands research at the University of Alberta, the University of Calgary, and the University of Lethbridge. Since September 1990, no new awards were made under this program. Current award holders are those to whom commitments were made earlier and are identified in the following lists:

University of Alberta

Chakrabartty, C.	Londry, K.
Chalaturnyk, R	Phadke, S. *
Chang, H.	Sanders, R.S.
Eastwood, J. †	Talman, S.
Korashek, F.	Udey, S.N. *
Le, L.	Vekred, K.

University of Calgary

Blenkensopp, S. *	Huang, H.
Daikow, D. †	Kohse, B.F.
Gupta, S.	Taylor, S.K.

* Fellowship.

† Supplement awarded to NSERC Scholar.

The scholarships are $17,728 per year for a maximum of two years and the research done normally leads to either a Masters or Doctoral degree. Fellowships are approximately $23,920 per year and are intended to assist post-doctoral scientists in furthering their training. An important innovation in 1990 was the supplementary award of $5200 to NSERC Scholars who chose to do oil sands research. Many of these people will eventually do research in Alberta's petroleum industry.

10.3 University Research Program

AOSTRA continues to support a wide range of oil sands and heavy oil related research projects at Canadian universities. The objective of this program is to help our professors and their many students do research that will assist the development of Alberta's oil sands and will transfer new technology and skilled young professionals to Alberta's petroleum industry. The projects are selected by a committee of leading scientists and engineers from Alberta's industry and universities.

The funding, now $2.5 million per year, still remains a significant part of AOSTRA's effort. The amount expended in the previous 15 years is $31,192,991.

This program covers many areas of practical interest ranging from fundamental research to new process development for the recovery and upgrading of bitumen and heavy oil. Since 1976, more than 500 graduate students and post-doctoral fellows have developed the needed special skills and obtained advanced degrees in the broad field of oil sands engineering and science. Most are working in Alberta's oil industry. More than 80 professors now consult in this industry and teach and do relevant research at Canadian universities.

Universities provide a special environment for doing projects that test "radical" or highly innovative concepts. This is probably a direct result of the emphasis on creativity in universities and the availability of bright graduate students seeking advanced degrees. Their projects yield much-needed data and understanding that help develop the technology. Brief descriptions of projects for this reporting period follow.

1. Dr. A.K. Ambastha of the University of Alberta is determining the applicability of pressure-falloff tests to provide a simple means of measuring the heated volume of the reservoir and other parameters that affect the performance of the steaming processes used to recover bitumen and heavy oil. Data from field tests and from numerical models of fractured wells, horizontal wells, composite reservoirs, etc. are being analyzed. Funds for this three-year project amount to $173,460.

2. Dr. M.C. Baird of Queen's University completed his development of water-soluble catalysts whose aqueous solutions dispersed finely in bitumen will catalyze the hydrogenation of bitumens at temperatures much lower than those of conventional refining processes. This project was funded at $80,000 over two years.

3. Drs. L.A. Behie and W.Y. Svrcek of the University of Calgary are generating basic kinetic data for ultrapyrolysis of Alberta heavy oil using a novel micro-reactor system and determining the amounts of ethylene, butadiene, and other products. Funding of this work amounts to $203,000 over three years.

4. Drs. D.W. Bennion and R.G. Moore of the University of Calgary completed their investigation of mechanisms of dry and wet in situ combustion processes used to recover bitumen from oil sands. A key part of this project measuring the slow oxidation and polymerization of bitumen at relatively low temperatures (about 250°C). Funding for this project extended into 1990 amounts to $325,000. Total funding for this project and those completed over the past 13 years is $2,293,764.

5. Drs. P.M. Boorman, R.A. Kydd, and T.S. Sorensen of the University of

Calgary are developing novel catalysts that may be used to hydrocrack or upgrade bitumen under relatively mild temperatures (about 410°C) and to enhance the yield of liquid products with low aromaticity. Funding of this project amounts to $198,682 over four years. Total funding of this project and previous projects completed since 1976 by Dr. Boorman amounts to $698,713.

6. Dr. R.M. Butler of the University of Calgary is doing theoretical- and physical-model studies of the steam-assisted gravity drainage process that uses horizontal wells for the recovery of heavy oils and bitumen. Funding of this three-year project is $330,000. Funding of previous studies amounts to $912,500.

7. Drs. F.S. Chute and F.E. Vermeulen of the University of Alberta completed their measurements of electrical properties of oil sands, development of physical models of electrical heating processes, and evaluation of the use of electrical power for selective heating of oil sands. Application for patent of their novel process for bitumen recovery has been made. Funding of this three-year project is $300,000 and for previous projects since 1978 is $567,633.

8. Dr. D.E. Cormack of the University of Toronto completed development of a three-dimensional numerical simulator for application to the steam-assisted gravity drainage process. He also investigated the effects of non-condensible gases on the development of steam chambers. Funding of this two-year project and earlier studies amounts to $215,310.

9. Dr. J.W. Costerton of the University of Calgary is investigating the use of bacteria to selectively plug high permeability zones in reservoirs and inhibit coning, thereby improving oil recovery by the conventional water flooding process. A process derived from this work is now patented and licensed to an Alberta company. A total of $797,000 has been allotted to this and earlier projects over eight years.

10. Dr. P.J. Crickmore of the University of Alberta is developing statistical methods of predicting the geology of a reservoir from data obtained from sparsely located wells. The method, fractal analysis, is applied also to describing mechanisms of production of bitumen. The cost of this project is $77,080 over two years.

11. Dr. F.A.L. Dullien of the University of Waterloo is doing laboratory studies to investigate a novel process using gas to displace residual oil from samples (cores) of an oil-bearing reservoir that has been water flooded. An X-ray CAT scanner is used to determine production history, saturations, and relative permeabilities of small elements of these heterogeneous cores. Funds for this three-year project amount to $239,160.

12. Dr. M.B. Dusseault of the University of Waterloo obtained geotechnical data needed to assess novel processes for transporting and depositing mine wastes currently deposited as overburden and tailings ponds. He showed that a mixture of lumps of clay and tailings may be pumped great distances through a pipeline and deposited as drained landfill without dispersing the clay. He began a new project studying the mechanics of the interactions of small particles of sand or clay and relating this to modelling processes of hydraulic fracturing and sand production. Funding for this project and previous ones since 1977 amounts to $792,477.

13. Dr. S.M. Farouq Ali of the University of Alberta is studying the use of small amounts of carbon dioxide gas to improve the commonly used water flooding process for recovery of Alberta's light oils. Also, he is developing new methods of control of mobility to improve recovery of heavy oil or bitumen from the Athabasca and Lloydminster deposits and improving a computer program that models oil recovery and fracturing of oil sands formations during injection of steam. Funding of these projects amounts to $1,871,068 over 10 years.

14. Dr. P.M. Fedorak of the University of Alberta is investigating the ability of certain fungi to metabolize asphaltenes that are a major component of bitumen and heavy oil. He has isolated certain enzymes that may be placed on porous sand and that will catalyze the decomposition of asphaltenes into useful light distillates. The cost of this three-year project and an earlier similar project with Dr. D.W.S. Westlake is $316,250.

15. Dr. M.R. Gray of the University of Alberta continues to develop methods to characterize heavy oils, bitumens, and other feedstocks in terms of functional groups and other chemical moieties and how they affect the kinetics of refining these feedstocks. The objective is to develop operating strategies that maximize the value of the liquid products. Funding of this three-year project and an earlier one with Dr. I.G. Dalla Lana amounts to $479,000.

16. Dr. R.E. Hayes of the University of Alberta is doing laboratory experiments to measure the dispersion of surfactants that have been added to a water flood used to recover oil. He developed a high-speed computer program that models the experiments and is extrapolating the results to oil field experience. The cost of this two-year project is $58,232.

17. Dr. L.G. Hepler of the University of Alberta completed his measurements of the kinetics and thermodynamics of oxidation of bitumen and obtained quantitative relationships useful in modeling in situ recovery processes. Funding for this two-year project and earlier ones on colloids, sludge treating, and gas dissolution in bitumen amounted to $1,116,988 over 12 years.

18. Dr. I.E. Hutcheon of the University of Calgary is analyzing the water, oil, and gas recovered from reservoirs that are being steamed or burned. From these analyses, and from results of other experiments measuring dissolution and precipitation of minerals, Dr. Hutcheon is able to estimate the thermal history of those recovered fluids. The cost of these projects and earlier ones completed over a nine-year period is $782,290.

19. Dr. A. Jeje of the University of Calgary is studying fundamental mechanisms that affect the efficiency of the hot water process used to extract bitumen from mined oil sands. Funding for this two-year project and for an earlier one on in situ oil recovery by injection of carbon dioxide gas is $118,520.

20. Dr. E.R. Kanasewich of the University of Alberta is developing improved geophysical methods of seismic imaging and tomography to determine oil and gas content of Alberta's reservoirs. It is intended that these methods be used to monitor progress of thermal processes used to recover bitumen and heavy oil. The cost of this three-year project and earlier ones with Dr. E. Nyland is $1,225,872.

21. Dr. Y. Koga of the University of British Columbia is developing a novel X-ray diffractometer that is capable of measuring with high angular resolution the slight scattering of X-rays by sub-micron sized particles. The intent is to develop a device for measuring quantitatively the amount and size of dilute suspensions of clay in oil or produced water. The cost of this three-year project is $151,709.

22. Dr. W.G. Laidlaw of the University of Calgary developed a computer program to model the flow of foams in water through an oil-bearing sand. The model is closely related to laboratory experiments and shows the deterministically chaotic path taken by these fluids. The objectives are to derive a better description of the mechanism of fluid flow than those currently used and to develop and improve descriptions of surfactant floods. The cost of this three-year project is $135,000.

23. Drs. S. Levine and B.D. Bowen of the University of British Columbia are using theory and experiment to identify the mechanisms by which fine particles and clays stabilize the emulsions that are found in oil sands tailings ponds. Funds for this seven-year project amount to $432,416.

24. Dr. F.J. Longstaffe is doing a detailed regional study of natural diagenesis in sands, sandstones, and shales of the Clearwater Formation near Cold Lake, Alberta. In his analysis of clays in samples of cores, he concludes that significant quantities of surface water, perhaps from nearby lakes, are penetrating part of the formation and causing swelling clays to be formed there. Funds for this two-year project and an earlier related one amount to $123,817.

25. Dr. B.C.-Y Lu of the University of Ottawa is doing laboratory experiments to measure phase equilibria of mixtures of water and bitumen under conditions obtained in in situ recovery processes. Funding for this project and an earlier one amounts to $286,460 over five years.

26. Dr. H. Machel of the University of Alberta is doing petrographic and geochemical studies of carbonate rocks and connate fluids obtained from the Grosmont and Hondo formations to identify and determine the effects of the major diagenetic processes. It is intended that these studies will provide a capability of predicting what portions of Alberta's great bituminous carbonate deposits may produce bitumen easily. The cost of this four-year project is $232,000.

27. Dr. J. Masliyah of the University of Alberta is studying methods of cleaning the froth that is obtained by flotation of hot slurries of oil sands and water. He is also developing a novel microwave process for removing water from bitumen The cost of these three-year and two-year projects amounts to $330,560.

28. Dr. K. Muehlenbachs of the University of Alberta is completing the measurements of concentrations of isotopes of hydrogen and carbon in current commercial and experimental processes for upgrading bitumen. The data show details of effects of certain catalysts on the "scrambling" of hydrogen and carbon moieties that occurs in these processes. Funding for this three-year project amounts to $203,000.

29. Dr. S.G. Pemberton of the University of Alberta is investigating the regional stratigraphy and depositional history of the North Athabasca oil sands deposit. Traces of fossil workings and of fossils provide good paleontological control of facies. Studies of data from many thousands of wells provide good regional predictive capability. Funds for these projects and previous related ones are $766,265.

30. Dr. D.Y. Peng of the University of Saskatchewan is developing an

equation of state that provides a thermodynamic description of continuous distributions of hydrocarbons found in bitumen/gas mixtures. Earlier, Dr. Peng and his colleague developed a simple equation of state that is widely used by Alberta's petroleum industry. This work provides additional capability to predict the viscosity of mixtures at various temperatures and pressures. Funds for this and an earlier project amount to $312,556 over four years.

31. Dr. V.R. Puttagunta of Lakehead University is continuing his work to develop a simple correlation to predict the viscosity of bitumen-gas mixtures over a wide range of pressures and temperatures. The cost of this three-year project and an earlier two-year project is $86,512.

32. Dr. J.A. Rogers of the University of Alberta is developing micro-encapsulation techniques to transport bacterial nutrients into a reservoir. Microcapsules of diameter less than one micron can be placed at depth in a reservoir to release contents over at least a 30-day period. This one-year project is related to one described earlier for Dr. Costerton and costs $55,000.

33. Dr. D.R. Schmitt of the University of Alberta developed an ultrasonic device that he has lowered in a wellbore to measure deformations of and near the wellbore and to observe fluid breakout. Results of observations taken while nearby wells are being steamed are being used to determine in situ horizontal stress directions as a function of time. Funds for this three-year project are $228,684.

34. Dr. T.J.T. Spanos of the University of Alberta is completing his development of fundamental mathematical expressions that describe flow of mixtures of bitumen, water, and gas in heavy oil reservoirs. These equations accurately predict the laboratory observation that oil and water may flow in opposite directions in the reservoir at conditions found in a water flood. Also, expressions have been developed to describe the propagation of seismic waves through an oil sands deposit. These expressions are now being incorporated into numerical models. The cost of this project and earlier ones amounts to $452,973 over eight years.

35. Dr. O.P. Strausz of the University of Alberta is doing laboratory experiments to assess the use of superacids for commercial hydrocracking of bitumen and heavy oil. Also, he is developing new processes such as continuous steam-flow coking for upgrading of bitumen. Funding for these two projects is $400,000 over four and one-half years. Funds for previous projects on the chemistry of bitumen, causes of poor recovery of bitumen from some deposits, and on soluble catalysts for hydrotreating amount to $3,180,184 over 12 years.

36. Dr. E.L. Tollefson of the University of Calgary is completing bench/pilot-scale experiments of a novel process to minimize bogging that can occur in a commercial fluidized-bed coker. Funds for this two-year project are $200,000 . Funds for earlier work on desulphurization of coke and on sludge treatment are $578,370 over eight years.

37. Dr. H. Vaziri of the Technical University of Nova Scotia has developed a computer program, ENHANS, that models stress and sloughing of sand near a well or mine shaft. He is improving this popular program to model further the flow of oil and water to the well and the beneficial effects of producing some sand along with the oil. The cost of these two projects is $164,760 over three years.

38. Dr. N.C. Wardlaw of the University of Calgary is doing microscopic studies of sandstones and carbonates obtained from Alberta reservoirs to determine the effects of factors such as wettability and pore geometry on fundamental processes important to enhanced recovery of bitumen and heavy oil. An important part of this work is developing methods to improve the performance of AOSTRA's patented AWACT process for recovering heavy oil. Funds for this project and earlier ones amount to $537,384 over six years.

Professors periodically report the progress in their research and assign ownership of their technology to AOSTRA. At the Technical Review Meeting and Seminar held each year in the fall, the professors and their students present the current results of their research. In 1990 more than 250 senior scientists and engineers from the oil industry, universities, and government attended the meeting to learn about the progress on 65 current and completed projects.

The AOSTRA/University/Industry ACCESS Program provides companies with reports of current research, regular interaction with researchers, non-exclusive technology use rights, and an opportunity to participate in project evaluation and selection. An Associate Membership category in this program allows companies to obtain membership privileges with somewhat restricted participation in evaluation of projects and technology use rights. In 1990/91, 19 companies participated in the program as full or associate members at annual fees of $50,000 or $10,000, respectively.

11 AOSTRA–ALBERTA RESEARCH COUNCIL PROGRAM

AOSTRA continues to support laboratory research on oil sands and heavy oils at the Alberta Research Council (ARC). This research is generally divided into two main programs: ***Core Research*** and ***Strategic Research***.

11.1 Core Research

The Core Research Program focuses mainly on the regional and generic problems common to much of the industry. The program provides an interface between fundamental and applied industrial research, complements expertise in universities and industry, and aids technology transfer and problem solving.

The Core Research projects are currently funded jointly with ARC and, in some cases, with support from industry. The three major programs of Core Research are as follows:

Oil Sands and Hydrocarbon Recovery Research

This was the final year of a five-year AOSTRA/ARC/Industry Joint Research Program. 1990/91 fiscal year expenditures were $3.0 million with industry providing approximately $0.7 million, with the balance being split 50/50 between AOSTRA and ARC. With active participation from industry, five multidisciplinary projects were designed to address identified technical needs, with both short- and longer-term objectives and schedules:

- To identify flow regimes where simple relative permeability concepts do not adequately represent flow behavior and to develop new theoretical relationships or modelling approaches where required.
- To develop processes and injection strategies for modifying and controlling flow patterns in homogeneous and heterogeneous reservoirs.
- To identify and develop advanced recovery processes which would have applications in field pilot trials.
- To provide a quantitative description of the geochemical processes occurring in near-well regions of the reservoir and to develop new remedial procedures that can counteract deleterious effects of scale formation, sand production, mineral dissolution and precipitation, and fines transport.
- To obtain experimental data for bitumen-gas and bitumen-gas-water systems and to develop correlations and models for calculating the properties of reservoir fluids under in situ conditions.

The program involves a total of approximately 27 person-years of professional and technical efforts and is closely coordinated.

Notable achievements in the whole five-year period (1986–1991) include:

- A unique experimental and theoretical capability was developed to study the flow of bituminous fluids through porous media by applying modern computerized imaging techniques. A specialized core flood apparatus equipped with X-ray CT (computed tomography) scanning capability provided data not previously available on flow parameters at elevated temperatures and pressures. These measurements were analyzed using theory embodied in the AOSTRA/ARC numerical simulator. This has led to new insights into the mechanisms of steam flow through sand and the predictions of reservoir recovery performance.

  CT imaging studies were conducted with the aim of understanding the bitumen mobilization mechanism and the flow processes in the steam zone. Numerical simulations of the unusual water saturations seen in CT images of these steam flooded cores confirmed the importance of accounting for capillary forces in core-scale experiments. The importance of capillary forces in oil recovery at the field scale was demonstrated by simulations of the steam drag recovery process.

  Under certain reservoir conditions, fine solids such as clays can be mobilized, transported, and deposited at pore throats, where they can reduce permeability. To quantify the effect of fines transport on reservoir productivity, a mechanistic fines transport model was developed based on experimentally verified colloidal, hydrodynamic, and filtration theories. The fines transport model was incorporated into the reservoir simulator which can now predict permeability damage associated with aqueous chemistry in field operations.

  Conditions prevalent in thermal heavy oil recovery processes often favor formation of water-in-oil

emulsions. Scoping studies using both field emulsions and laboratory-prepared emulsions have demonstrated the inadequacy of using bulk rheological parameters and the effect of dynamic flow on the character of the emulsion. Concepts were developed which describe the emulsion flow behavior in terms of capillary number (ratio of viscous to capillary forces) on permeability reduction when emulsified droplets are either trapped or dispersed. The characterization of emulsion flow remains a major theoretical and experimental challenge which will be addressed in the new five-year program.

- Many steam injection processes suffer from poor conformance, which means that only a small fraction of the pay zone can be contacted by the displacing fluid, resulting in early abandonment of many fields. Injection of a foam, consisting of surfactant and non-condensible gas in combination with steam, provides a means of modifying reservoir conformance and improving productivity. Foam flow behavior studies were initiated to develop injection strategies for typical Alberta steam conditions as well as provide input parameters to a foam transport model. The model developed was used in history-matching of three-dimensional and semi-scaled conformance experiments in order to better understand the effect of foam on oil recovery and to predict recovery from a hypothetical reservoir using the injection of steam followed by steam-foam.

  A major finding of the studies was that very low residual oil saturation in the steam zone must be achieved to ensure the stability and propagation of the foam. To improve the rate of foam propagation, a new concept was developed which employs the use of a pre-foam slug. The slug is designed to reduce residual oil saturation and may consist of a low interfacial tension chemical, solvent, or air. The concept was tested in both hot water-foam and steam-foam runs as a function of frontal velocity, surfactant type and slug size, and concentration. The results revealed large improvements in both the rate and extent of foam formation and propagation. A patent disclosure for field application of the novel technology has been prepared.

  Under some reservoir conditions, high concentrations of residual oil or divalent ions may strongly inhibit foam formation. In such cases, it is desirable to have an alternative means of conformance control. Polymer gels were tested for their ability to function as blocking agents at temperatures up to 300°C. A phenoformaldehyde gel was shown to significantly reduce sandpack permeability by two mechanisms: at temperatures below about 200°C, the gel existed as a continuous polymer network, resulting in orders-of-magnitude permeability reductions; above 200°C, gel particles released by partial degradation plugged pore throats to give smaller, but still significant permeability reductions. This work demonstrated that gels may function as steam blocking and diverting agents, even under the extreme temperature and pressure conditions of recovery operations in Alberta's heavy oil reservoirs. Results have demonstrated that gel-foams can produce a more effective diversion than foam alone at temperatures up to 200°C. A patent disclosure on foams stabilized by gels has been submitted. Development of a comprehensive gel-foam technology package for reservoir application will continue in the new program.

- Three novel recovery processes (hot water-caustic, hot water-carbon dioxide, hot water-caustic-carbon dioxide) were developed and patented. These processes recovered over 50% of the initial bitumen-in-place, a substantial improvement over the recovery obtained using hot water alone.

  In reservoirs where there is inadequate gas saturation, the role of gases added to the injected steam is to increase the reservoir energy, contact new unheated zones, and promote easier movement of oil in the reservoirs. Injection strategies for steam and steam-gas processes were evaluated in scaled physical models representing one-eighth of a five-spot pattern with a communicating bottom water zone. The use of flue gas as a steam additive showed promise in accelerating heat transfer in the communication zone, and co-injection of CO_2 with steam improved the recovery rate and final recovery.

  Another novel recovery process that has been developed is the co-injection of steam with air. Planning is under way to utilize this process at a pilot in Athabasca. The steam-air process can dramatically increase the pressure drop across a partially depleted oil sand zone. This is because air

changes the properties of the heavy oil and aqueous phases in the depleted zone, and deposits asphaltene and coke which impede fluid flow through pore throats. A patent application for the injection of air and other oxidizing agents or solvents to create steam diversion by asphaltene deposition in the depleted zone has been prepared.

- Detailed examination of drill core from various field pilots has established the connate water chemistry and complex clay mineralogy of the Clearwater Formation reservoirs in the Cold Lake area. The basic clay, berthierine, is now recognized as an important component of the formation. Previously the acid clay, kaolinite, was thought to dominate. These two clays react very differently in a steam flood environment. Overgrowths as a result of these reactions can drastically affect the permeability and thereby the productivity of the reservoirs.

  Carbon dioxide production has been shown to be mainly due to the decomposition of carbonate minerals by reaction with acid clays such as kaolinite. This provides an in situ source of carbon dioxide. The carbonate minerals are distributed irregularly as disseminated detrital dolomite grains and calcite-cemented barriers in the reservoir and offer the potential of an on/off source of CO_2 to stimulate heavy oil production. Some care must be taken to protect the chemical stability of barriers that are important to the recovery process design.

  Produced-fluid chemistry has been used to develop in situ tracer applications based on the concentration of the inert chloride ion, and to monitor reservoir temperatures on the basis of dissolved silica. A series of potential geothermometers were tested in the laboratory by measuring the water chemistry in quasi-equilibrium with samples from the major heavy oil deposits of Alberta. The silica geothermometer can be used globally to determine reservoir process temperatures in cyclic steam recovery. Kinetic models for quartz dissolution and precipitation developed in the previous program were also integrated into the reservoir model.

  Scale formation in producing wells and scale deposition on downhole equipment are serious problems in many steam recovery operations. A monitoring program at BP Wolf Lake and Esso Cold Lake showed that the major component of the scale is calcite, with significant amounts of precipitated quartz and amorphous silica. The incidence of scale formation increases sharply near the beginning of a steam cycle. By monitoring saturation indices early in the cycle, scale inhibitor applications can be optimized.

  In the laboratory, CO_2 and O_2 rapidly corrode carbon steel, and high pH results in rapid dissolution of silica gravel packs. Operational conditions which promote wetting of the tubulars by the produced oil reduce scale formation and corrosion. Studies on the wettability of well materials under various flow conditions can predict periods in the production cycle that are most susceptible to calcite deposition and corrosion. Methods of measuring wettability underflow have been developed.

- Specified precision equipment and methodology for measuring pressure-volume-temperature (PVT) relationships and viscosities of bitumen/gas system were developed during the earlier period of the program. A visual cell apparatus was constructed in order to observe the phase boundaries in bitumen-gas-water systems. Accurate measurements on water-containing systems were handicapped by major difficulties in distinguishing between emulsified and dissolved water in bitumen phase.

  A data base for PVT and phase behavior of Athabasca, Cold Lake, and Peace River has been established. A critical review of this data base was also completed encompassing all phase equilibrium data and experimental methods for bitumen and heavy oil systems.

Transfer of technology from this program is via the AOSTRA/ARC/ Industry Access Program through which participating companies are involved in all stages of project definition, direction, and management. The Access Member companies are provided with direct access to research results, commercial use rights of project technology, and the opportunity to play a major role in developing the research program. The annual membership fee for the Access Program amounts to $60,000, equivalent to 2% of the total annual budget for the program.

A Program and Policy Committee, which is a high-level decision-making body, was established in 1989/90 having responsibility for long-range planning and policy development for the program.

The technical progress of the program is monitored by a Technical Committee, composed of Access Member representatives and the AOSTRA and ARC program managers. Interaction at the working level is provided by project subcommittees, which include research or engineering staff from each Access Member company, AOSTRA, and ARC.

A marketing meeting to recruit new industrial members was held on November 22, 1990 in Calgary. As of now, five companies, including Suncor, Chevron, PanCanadian, Norcen, and Mobil have submitted letters of intent to join the program and new access agreements are to be signed shortly by the parties involved. With the increasing commitment, it is anticipated that CANMET will become a co-sponsor of the program.

Regional Geology Studies

This program was originally supported on an equal tripartite basis by AOSTRA, ARC, and the Alberta Department of Energy from 1986 to 1990. Each agency contributed $400,000 per year. Since April 1, 1990, the grant from the Alberta Department of Energy, held by ARC in trust, has been exhausted. AOSTRA and ARC each contribute $500,000 in the final year of the five-year program, 1990/91, to capitalize upon the existing geological expertise and data base in oil sands. The research program focuses on regional geological characterization of the unmapped portions of the oil sands deposits and on parameter estimation for detailed reservoir modelling.

The resource characterization studies provide fundamental insight into the stratigraphic and structure setting of the oil sands deposits, define the sedimentologic and mineralogic framework of the reservoir horizons, and document fluid distribution and saturation. Acquisition of this information yields baseline data against which decisions on resource assessment, development, and recovery strategies can be addressed. Complementary to these more regional investigations, the detailed geological reservoir modelling studies are focused on the finer-scale attributes of oil sand and heavy oil reservoir fabric. These studies are intended to provide more sophisticated insight into the identification, scaling, and quantitative modelling of geological and petrophysical parameters.

The program had significant achievements in the fifth year. In resource characterization, the report on the geology of the McMurray/ Wabiskaw deposit in the Athabasca central region of northeastern Alberta was revised and incorporated into the AOSTRA Technical Publication Series (#7). In the reservoir analysis project, a report entitled "Reservoir Characterization — A Case Study: The Provost Upper Mannville B Pool" was completed and this report will form the basis for a publication in the AOSTRA Technical Publication Series. This study also resulted in a new initiative on the modelling of McMurray Formation to optimize bitumen production from both mining and in situ operations. Closely spaced cores and mineface data from the Syncrude mine are being used to document the geological viability within the McMurray Formation. The detailed geological framework would then be used to model flow within the formation for application to existing in situ projects, such as the UTF. The study will provide a detailed geological framework for future oil sands development in the McMurray Formation.

Thus, the joint geology program has attained many significant achievements that spanned a wide range of activities over the past five years. The program has received strong support from the public and private sectors and has been recognized as providing a basic service to industry.

Hydrocarbon Processing and Upgrading Program

This is the fourth year of a five-year arrangement between AOSTRA and ARC on a 50/50 basis. In the 1990/91 fiscal year, approximately $800,000 was expended. During the year, the major activities in the program were concentrated in the following areas:

- studies of the fundamental aspects of high-conversion hydrocracking processes;
- measurements of process parameters relevant to the control of coke formation in upgrading processes;
- development and evaluation of novel catalysts for upgrading of bitumen and bitumen-derived feedstocks;
- determination of the feasibility of using a spray reactor for primary upgrading of bitumen; and
- generation of vapor-liquid equilibrium (VLE) data for high-conversion process conditions.

Significant progress has been made in achieving the research objectives. The highlights of these achievements are as follows:

- In the "High Conversion Processes" project, a mechanism of homogeneous catalyst interaction with bitumen and hydrogen has been investigated using an "in situ"

FTIR high-pressure, high-temperature cell. Results from this study have been used to support patent application claims for the AOSTRA/ARC high-conversion process. Tracer experiments performed in a 4-kg/h pilot plant have provided important data on the degree of vaporization in the reactor under severe process conditions.

- In the "Mechanism of Coke Formation" project the research has been focused on the development of a phase diagram which will allow the prediction of the extent of solids precipitation in a hydrocracker. A series of experiments has been performed in a 2-kg/h bench unit to generate data for the support of two patent applications in the area of coke suppression in upgrading processes.

- In the "Novel Catalytic Processes" project the experimental results have demonstrated that catalyst support, pore size, and pore size distribution play an important role in upgrading residua. Data obtained over a range of operating conditions have shown that the use of delaminated pillared clays as catalyst support results in an increased selectivity for asphaltene conversion as compared to commercial alumina supports. A patent application has been filed based on this development.

11.2 Strategic Research

The Strategic Research Program is designed to provide a confidential forum for applied proprietary research and development to meet AOSTRA's specific needs in all areas of operation.

The Strategic Research Program has three broad objectives:

- To apply concepts, results and insights gained from laboratory research to field situations.
- To address specific problems from field operations.
- To investigate and evaluate AOSTRA technology for potential broader application to resource development.

The program is funded entirely by AOSTRA; approximately $1.5 million was expended in the 1990/91 fiscal year. The Program Committee, which consists of representatives from three different directorates of AOSTRA and one representative from ARC, is continually monitoring progress of the program and ensuring the program conforms with AOSTRA's priorities. Research projects which have been identified by the Program Committee, are listed in the following four major fields.

a) In Situ Reservoir-Related Research, including geological investigations, whose objective is to develop advanced recovery processes for difficult-to-produce reservoirs:
   - Reservoir Scale Outcrop Studies and Testing of Predictive Models for Permeability Against Reservoir Performance Data
   - Core Logging and Update of Facies and Reservoir
   - Top-Down Gas Displacement Between Horizontal Wells for the Recovery of Heavy Oil from Thin Reservoirs with Underlying Water
   - Multilayered Reservoirs: Applicable Strategies and/or Processes

b) In Situ Production-Related Research, in which practical solutions for identified field production problems are investigated:
   - Geotextile Filters for Thermorecovery Wells in the Athabasca and Lloydminster Fields
   - AOSTRA Multiclient Thermal Pump Studies

c) Surface Extraction and Upgrading Research, aimed at significant improvement of mined oil sand extraction and subsequent bitumen upgrading:
   - Studies on Oil Sand Extraction Processes
   - Development of a Hydrocracker
   - Mathematical Modelling of the AOSTRA Taciuk Processor

d) Environmental Research, in which procedures for reducing the environmental impact of oil recovery are investigated:
   - Produced Water Treatment
   - Assessment of Potential Groundwater Contamination Caused by the Migration of EOR Production Fluids, Phase 2

Much progress has been achieved in every aspect of the program in 1990/91. A novel recovery process aiming to maximize the gravity effect and to reduce the negative effect of layers was suggested and assessed using numerical techniques. This process makes full use of novel drilling strategies from the surface, where several complex vertical wells branching from a horizontal well penetrate the impervious reservoir

layers and reach the near–cap rock reservoir zone. It has a great potential for use in complex reservoir situations and a patent application is being made.

11.3 Sample Bank

In addition to the research and development programs such as the Core Research Program and the Strategic Research Program, AOSTRA also continues to support a service project at ARC, the Sample Bank, with approximately 1.5 person-years effort. Approximately $120,000 was expended in 1990/91. The prime purpose of the Sample Bank is to support research and development of all phases of oil sands and heavy oil technology by providing "standard" oil sands, bitumen, and other related samples to research workers around the world. During the year, the Sample Bank distributed a total of 19 tonnes of bitumen, oil sands, heavy oil, and related materials in 35 shipments. The value of these shipments was $31,150.

12 PROGRAMS AT OTHER RESEARCH ORGANIZATIONS

12.1 Computer Modelling Group

AOSTRA and the Computer Modelling Group (CMG) entered into a five-year program of Reservoir Simulation Research beginning April 1, 1986. Initially, two advanced thermal simulators, Thermal Wellbore Simulator (THEWS) and Steam Additive Reservoir Simulator (STARS), were developed. These two simulators were further validated and enhanced. In the past year, THEWS was successfully coupled to STARS and is being tested on a horizontal well case.

In 1990/91, AOSTRA continued to support CMG with $220,000, equivalent to two person-years of effort. This program consists of five projects:

- Validation of THEWS/STARS in field-scale simulation using UTF information.
- Validation and enhancement of dual-porosity modelling in thermal simulation using the data of the Buffalo Creek pilot.
- Emulsion modelling based on Dispensed Component Concept. This project is being conducted in close cooperation with ARC. It will continue in 1991/92 and will examine the in situ formation of emulsions.
- Technology transfer to ARC and AOSTRA.
- CMG support of AOSTRA staff in the use of CMG simulators.

12.2 Petroleum Recovery Institute

During the 1990/91 fiscal year AOSTRA provided continued support to the Petroleum Recovery Institute (PRI) by matching industry membership contributions to a maximum of $1 million. PRI was also financially supported by 24 industry members during the fiscal year.

Four major areas of research in the field of enhanced oil recovery technology are currently being investigated by PRI. The research areas are gas flooding (miscible displacement), sweep efficiency improvement, heavy oil recovery, and chemical flooding. AOSTRA and industry members have access to the results of this research work which are available for potential field application. In addition PRI provides technical expertise to AOSTRA for special laboratory studies and technical performance analysis of AOSTRA projects.

In 1990/91, AOSTRA participated in a multiclient study being jointly conducted by PRI and British Columbia Research Council to investigate the use of pulp and paper by-products as a co-surfactant additive to enhance alkaline flooding and as a resin for sand consolidation. The study indicated that tall oil, a pulp and paper processing by-product, showed promise in replacing more expensive surfactants in surfactant- and polymer-enhanced alkaline flooding. AOSTRA is also participating in a multiclient study being conducted by PRI to investigate the occurrence and significance of fines and pyrobitumen in selected Alberta carbonate reservoirs.

AOSTRA has an agreement with PRI to patent and act as exclusive license agents for technology developed at PRI with AOSTRA as owner of the technology.

12.3 Saskatchewan Research Council Multiclient Research Program

AOSTRA participated in a number of multiclient research programs being conducted by the Saskatchewan Research Council (SRC) in the areas of emulsion research, in situ combustion, enhanced oil recovery by CO2 injection, miscible oil displacement, and horizontal well technology. In 1990/91 AOSTRA supported SRC to the extent of $75,000 and received the results of the $1.73 million research program conducted by SRC.

12.4 Centre for Frontier Engineering Research (CFER)

CFER core programs addressing well-related technologies including wear problems in oil production wells, casing formation interaction, tubing joint integrity, sucker rod tubing wear, and slant well directional control, continued to provide valuable results. AOSTRA funds and actively participates in this program at $25,000 per year.

The scope of a multiclient program to qualify Grade 55 casing for thermal wells was enlarged to include tests of oversized buttress couplings with the joining of an additional participant. The study is expected to be completed in mid-1991 at a cost to AOSTRA of $30,000.

A three-year multiclient study of the mechanics of sand production with the goal of improving the economics of oil recovery was initiated in January 1991. AOSTRA and five industry participants, as well as NSERC, are supporting the project expected to cost $1,523,500. The study will address all aspects of sand production and will entail detailed assessment of available field data, laboratory study, field testing, and numerical modelling. AOSTRA's cost for the project will be $150,000.

13 INTERNATIONAL PROGRAMS

Introduction

AOSTRA continued an active international program during 1990/91 with the signing of five memoranda of understanding with Argentina, China (SINOPEC), Japan, Azerbaijan and Kazakhstan (two Soviet Republics). Negotiations under way with Nigeria, Brazil, Ecuador, India, and Albania. AOSTRA staff have also been actively involved in a number of international activities, both domestically (hosting of incoming visitors and trainees) and abroad (participating in fact-finding missions and technical conferences/ exhibits).

AOSTRA continues to work closely with Alberta Economic Development and Trade and with Industry, Science and Technology Canada in promoting Alberta goods and services around the world. This is achieved primarily through AOSTRA's contacts, credibility, and acceptance that were developed from its activities related to memorandums of understanding, and also by active participation in trade shows, seminars, and trade delegations. AOSTRA also continues to promote the sale of its own technology and is having success in developing sales for the ATP technology as well as laying the groundwork for sales of several in situ technologies.

UNITAR

The 5th UNITAR conference was postponed from February 17–22 to August 4–9, 1991. The technical program and exhibit will remain the same. Petróleos de Venezuela, S.A. (PDVSA) has chosen AOSTRA to publish the proceedings. AOSTRA has prepared an article for the Heavy Oiler issue, scheduled to be issued during the 5th UNITAR conference, dealing with AOSTRA's international involvement and technology transfer to developing countries.

UNITAR has made major progress over the last two years in restructuring itself to fulfill its original mandate and potential more effectively. Further progress has been limited due to severe financial restrictions. AOSTRA, PDVSA, and the Department of Energy have recently increased their contribution, and AOSTRA and PDVSA have renewed their commitment to supply the director and deputy director. This new commitment should see a revitalized centre playing an active role in technology exchange and training over the next few years.

China

Activities between AOSTRA and the China National Petroleum Corporation (CNPC), including its subsidiaries, have been revitalized in 1990/91 after a one-year period of relatively low-key relations due to the events of June 4, 1989 in China. CNPC actively maintained its participation in AOSTRA's University and ARC Access Programs by sending representatives to attend the Annual Technical Review Meetings and Seminars. The President of CNPC, Dr. Wang Tao, also accepted Premier Getty's invitation to visit Alberta in mid-April 1991, heading an 11-person delegation.

The successful results derived from the first Canada-China Heavy Oil Symposium in 1987 and the 4th UNITAR/UNDP Conference in 1988 led us to believe that there was enough desire to hold the Second Canada-China Heavy Oil Technology Symposium in 1990. This four-day symposium, which began on October 29, 1990, was jointly organized by AOSTRA and CNPC. The Alberta and Canadian Governments once again provided their support to the symposium. Besides accomplishing its objectives of information exchange and technology transfer, the symposium

provided a good opportunity for Canadian suppliers of products and services to promote their businesses.

Concluding cooperation agreement, Guo Zifu, Vice President of SINOPEC International and William Yurko of AOSTRA. Looking on, at centre, is David Redford.

During the Second Canada-China Heavy Oil Technology Symposium, the senior members of AOSTRA's delegation were presented with special honorary awards by CNPC. While in China, AOSTRA also signed a Memorandum of Understanding with SINOPEC International which is the international arm of the China Petrochemicals Corporation (SINOPEC). SINOPEC is a state-owned enterprise specializing in the downstream operation of the petroleum industry in China. AOSTRA will join SINOPEC to co-sponsor an international symposium on heavy oil and residue upgrading and utilization in May 1992.

The Henan Petroleum Exploration Bureau (HPEB), under the terms of an agreement signed in 1989, sent two groups to Alberta for training. The first group, consisting of two oil field geologists, worked at the Alberta Geological Survey for two months and studied image analytical techniques and reservoir description and modelling. In return, AOSTRA recently sent one geologist to Henan to help set up an Image Analytical Laboratory. The other group, including two engineers, are receiving six months of on-the-job training with Syncrude Research in Edmonton for modern heavy oil and oil sands analytical procedures and techniques.

Soviet Union

The return visit by a Soviet delegation, for the two AOSTRA specialists who spent three months in the USSR in 1989, took place from April to June 1990. For the last three weeks of their visit, the three Soviet specialists were joined by two senior officials from their organization, ISTC "Oil Recovery." This group was in Alberta to study AOSTRA technology, visit research and field projects, and meet with Alberta companies regarding investment opportunities in the USSR in enhanced recovery. Serious discussions also took place for the opening of a joint office in Moscow to facilitate technology transfer between the two countries.

Following the visit of a Soviet delegation to Alberta, AOSTRA attendance at the Neftegaz 1990 oil and gas show in Moscow, and the visit by an AOSTRA delegation to various parts of the Soviet Union, a lot of interest was generated by the ATP in that country. We have subsequently received several enquiries about sales of the unit, and are waiting to obtain more information about potential buyers, and planned usage and location before sending a delegation to the USSR to further discuss the matter. Requests from Soviet groups for entering into joint venture agreements were also received as a result of AOSTRA's attendance at Neftegaz 1990. They were answered by suggesting the appropriate business contact for such ventures.

During the visit by an AOSTRA delegation to the USSR, letters of intent were signed for testing of oil sands and sludge samples using the ATP with two groups that fall under the State Committee for Science and Technology, with whom AOSTRA has a Memorandum of Understanding. The work on each project is to start with the shipment of the samples to be tested at UMATAC's pilot plant.

A three-week visit of a delegation from the Kazakh SSR followed the signing of a Memorandum of Understanding with the Research and Production Association "Dortekhnika." This group is primarily interested in using mined oil sands for road paving material. They were acquainted with in situ exploitation technology of bitumen from shallow oil sands deposits (slant well drilling, steam-assisted gravity drainage with horizontal wells), and with the ATP operation. As a result of this visit, a letter of agreement was signed for testing oil sands samples from Kazakhstan to prepare a road paving precursor directly from the feed material using the ATP.

A five-person Kazneftebitum/ISTC delegation visited Alberta for 10 days in early January 1991. Meetings and field visits were organized with Alberta government and private sector groups. Their main interests were in joint venture and staff exchange possibilities, mainly in the areas of oil sands mining and in situ operations. They were also interested in the ATP, and offered to purchase two units. A Statement of Principles was signed before their departure, so that both parties can consider future technological exchanges.

A delegation from the Institute for Solving Problems of Deep Oil and Gas

Deposits of the Academy of Sciences of the Azerbaijan SSR visited Alberta for a two-week period. Meetings and field visits were organized similar to those for the Kazneftebitum delegation, but were more research-oriented. A Memorandum of Understanding was ratified during their visit. A letter of protocol detailing future collaboration and a Preliminary Technological Perspective for treating oil sands using the ATP were prepared for consideration by Dr. Abasov. They have agreed on the protocol, which will pave the way to collaborative projects. Of all the dealings so far with the Soviet Union, this group has shown the most enthusiasm and willingness to enter into technological cooperation.

Hungary

Dr. Maria Tóth and a colleague from the Hungarian Hydrocarbon Institute spent about six months at the University of Calgary's combustion laboratories to conduct combustion tube experiments using Hungarian technology related to the Countess B pool. The results of this international collaboration are very promising for application of in situ combustion technology to Alberta's light and medium heavy crudes. The summary report contains a proposal for the application of the new technology at PanCanadian's Countess pilot. PanCanadian have expressed an interest in obtaining these data, and eventually using this newly developed technology. As well, two invention disclosures have been filed. A return visit for three researchers from the University of Calgary's Combustion Group is planned for later in the spring to the Hungarian Hydrocarbon Institute laboratories.

The Hungarian Oil Trust has proposed to conduct up to $200,000 worth of research at the University of Calgary's combustion laboratory. This effort, together with research work in Hungary, would form the basis for a field application in Hungary of the jointly developed AOSTRA/HHI combustion technology. AOSTRA will be kept informed of the progress of this work.

Cuba

UMATAC completed preliminary test work on Cuban oil sands (marl) samples from the Marga deposit received in the summer of 1990. The results of the treatability tests, based on modified Fisher assays and batch pyrolysis tests, indicate that the Cuban marl, a calcareous clay or intermixture of clay and particles of calcite or dolomite, has low water content, gives attractive oil yields (145 L/t), and is therefore amenable to treatment and production of oil by the ATP. The deposit covers an extensive area and is 200 metres thick. Unfortunately it lies 200 metres below the surface. Present studies centre on adapting borehole mining techniques to this deposit. Permeabilities in the deposit are too low to permit in situ recovery.

Two Cuban experts, Messrs. David Tavares and Jesus Rios, arrived in early March for a three-month training period to conduct reservoir engineering studies on their heavy oil reservoirs, Varadero and Boca de Jaruco. Both reservoirs are highly fractured carbonates containing 12–15°API oil at 60°C. As the reservoir pressure declines during primary production, a secondary gas cap is formed, leading to high-producing gas-oil ratios. The dual porosity/dual permeability option of the CMG simulator IMEX is being used for history matching purposes and evaluation of new exploitation strategies.

Trinidad

The Trinidad and Tobago Oil Company Ltd. (TRINTOC) has expressed interest in the AOSTRA Taciuk Processor (ATP) for potential use in exploiting the Lower Maren L'Enfer Oil Sands Deposits in Trinidad. Steps are under way to examine the physical and chemical characteristics of these oil sands at the Alberta Research Council, and to batch test oil sands samples at the UMATAC pilot plant in Calgary to determine oil quality and oil yield predictions. Upon satisfactory results of these tests, a pre-feasibility study is planned. Negotiations are also under way to obtain up to $500,000 in CIDA funding for a Canadian engineering company to do a pre-feasibility study on an oil sands project in Trinidad using ATP technology.

Venezuela

An implementing agreement for the participation of Venezuelan and Canadian engineers in the International Cooperative M.Eng. Program at the University of Calgary under the terms of the agreement between AOSTRA and Petróleos de Venezuela, S.A. has been drafted. It is presently being reviewed by the Venezuelans, who seem interested in this program.

The annual Memorandum of Understanding meeting between AOSTRA and PDVSA was held in February 1991 in Caracas, and progress to date was reviewed by both parties. A test using the HDH Process with Alberta feedstock was performed this quarter on the 0.3-BPD unit. If the results are positive, the second phase of testing on the 10-BPD unit will be undertaken.

Specific areas of common interest for research projects have been identified

as Reservoir Characterization and Biotechnology/Microbial Processes. Some work is already being conducted under the AOSTRA/University Research Program, of which PDVSA is an associate member, and some work is planned under the new AOSTRA/ARC/Industry Research Program, in which PDVSA may have an interest.

Discussion also revolved around exchange of research and field personnel for training purposes. The Venezuelans favor assignments ranging from 18 months to two years for the training to be profitable both ways.

Nigeria

Negotiations have been successfully completed with the Nigerian Presidential Committee on the implementation of the bitumen project for the exchange of technical information and cooperation. Nigeria has a rich oil sand deposit containing in excess of 30 billion barrels of bitumen. The deposit outcrops, can be mined, and has sections suitable for in situ recovery. Nigeria, while a major light oil producer, imports bitumen from Venezuela for asphalt and lubricating oil production. They are very keen to produce their own resource.

U.S.A.

Under the Canada/U.S. DOE Memorandum of Understanding, of which AOSTRA is a signatory, AOSTRA and DOE took an active role in each others' university research programs and attended each others' access meetings. In addition AOSTRA, together with CANMET, completed an assessment report on seismic work related to the GLISP project. The resulting report will be issued as activity under the Memorandum of Understanding. AOSTRA also followed closely and gave advice on the in situ parametric combustion laboratory research project sponsored by CANMET at the University of Calgary and the corresponding project sponsored by DOE in the U.S.A. Recently DOE has made arrangements to supply oil-bearing diatomite samples from the U.S.A. for testing in the AOSTRA Taciuk Processor. Negotiations are also proceeding for a jointly funded project in horizontal wells, possibly in the area of improved drilling technology. DOE and the Saskatchewan Department of Mines and Minerals have also expressed an interest in a joint project on field upgrading of heavy oils.

Japan

In November 1990, AOSTRA representatives visited Japan and were present during the signing of an agreement between AOSTRA and the Japanese National Research Institute for Pollution and Resources (NPIPR). Cooperative research activities will centre on upgrading technology and on the use of the ATP technology for waste cleanup.

Argentina

The Memorandum of Understanding with the Argentinean National Oil Company (YPF) has been ratified by AOSTRA, preparing the way for collaboration. Initially, the Argentinians are interested in modernizing their enhanced oil recovery R&D laboratories and in expanding their thermal recovery program.

Brazil

Following a few years of effort, the Research and Development Center of the Brazilian National Oil Company (CENPES/PETROBRAS) has agreed to execute a formal agreement with AOSTRA. CENPES is particularly interested in establishing a modern thermal recovery laboratory. AOSTRA is also interested in the sale of the ATP technology for oil shale fines recovery and for refinery sludge. AOSTRA has suggested that this agreement be signed during a visit by AOSTRA staff during August 1991.

Ecuador

The English and Spanish versions of the Memorandum of Understanding with PETROECUADOR have been finalized following approval by FIGA. Signed copies of these agreements have been sent to Ecuador and it has been suggested that AOSTRA staff visit Ecuador following the 5th UNITAR conference in Caracas for further discussions on technical cooperation and staff training. Ecuador has heavy oil and oil sand deposits of perhaps 200 billion barrels.

India

Discussions with the Institute of Reservoir Studies of the Oil and Natural Gas Commission of India (IRS/ONGC) have been active, and we are nearing the signing of an agreement. Two experts from IRS/ONGC visited Alberta to familiarize themselves with combustion-related research and field facilities in April. They were also interested in horizontal well and anti-water-coning technologies.

France

AOSTRA will be a sponsor and a participant (presenting a paper entitled "Hydrocarbon-Contaminated Site Clean-up using the AOSTRA Taciuk Process Technology" by W.J. Yurko et al.) at the Canada-Europe Meeting on Environment and Waste to be held May 29–31, 1991, in Montpellier, France.

Contacts have been made with the Institut Français du Pétrole to start discussions for collaborative work. Discussions on collaboration/exchange of technical information were also held with a representative of the the Société Nationale Elf Aquitaine Production.

Germany

Further talks were conducted with GKSS, the official German Government representative for the Canada-Germany Science and Technology Cooperative agreement. AOSTRA drafted a letter of intent, outlining, but not restricted to, specific cooperative projects. The Germans would prefer to sign project agreements rather than a Memorandum of Understanding. This document is under review by the Germans at the present time.

Albania

Negotiations to develop a working relationship have started with Teknoimport, the Albanian Enterprise for Foreign Trade which is interested in developing its country's bituminous sands. A standard Memorandum of Understanding was sent to them, but no exploratory visit has taken place given the current political unrest in that country.

Romania

As part of renewing our relationship with Romania, we have received an invitation to visit their Research and Design Institute for Oil and Gas (ICPPG). As time constraints do not allow an immediate visit to Romania, a delegation from ICPPG was invited to come to Alberta during the second quarter of 1991.

14 TRAINING PROGRAMS

AOSTRA continues to provide training opportunities for young Albertans to obtain experience in hydrocarbon recovery and processing. Four main programs were conducted:

NAIT/SAIT Program

This program employed 20 NAIT/SAIT students for a four-month period during the summer between their first and second academic years of training. Students were employed on a variety of AOSTRA projects.

Co-op Program

This employs engineering students who are on the industrial portion of their co-op training program. Students are employed at AOSTRA's Calgary office for periods of four or eight months with up to six students at any one time being employed.

New Graduate Assistance Program

This program gives new university graduates in engineering and geology an opportunity to work for two years and obtain their work experience required for professional registration. Six recent graduates are employed at AOSTRA's Calgary and Edmonton offices on this program.

University Summer Student Program

This program takes top quality students who have completed second- or third-year university training and employs them with university professors who are working on AOSTRA projects, thus giving them the opportunity to become familiar with the potential of doing graduate work in hydrocarbon recovery and processing. AOSTRA employed 21 students in this program.

15 INDUSTRIAL POST-DOCTORAL FELLOWSHIP PROGRAM

In 1983 AOSTRA initiated its Industrial Post-Doctoral Fellowship Program which was designed to assist the transition of post-doctoral researchers from an academic to an industrial environment. During the two-year term of the award, valued at $22,500 per year, the AOSTRA Industrial Fellow conducts a research project in the laboratory of the sponsoring company which provides the space, equipment, and support personnel required for the proper conduct of the research.

During fiscal year 1990/91 there were two holders of the award:

- Dr. Khoon-Sin Tan is responsible for evaluation of Nuclear Magnetic Resonance (NMR) technology for use by Syncrude through the design and completion of a variety of experiments and to act as a technical interface with external

laboratories carrying out contract NMR work.

- Dr. Laurie J. Danielson is working on the fundamental aspects of the sludge disposal problem at Syncrude with the aid of scanning electron microscopy, X-ray diffraction, and NMR spectroscopy.

16 INVENTORS GRANT ASSISTANCE PROGRAM

The Inventors Grant Assistance Program (IGAP), first implemented in 1983, was continued during fiscal 1990/91. The purpose of IGAP is to encourage and assist inventors to develop inventions beyond the idea and concept stage so that conventional funding for commercialization may be obtained. Amounts to a maximum of $50,000 may be awarded to individuals or companies for use in developing inventions. AOSTRA does not earn any use rights to the inventions and the only requirement on the part of the inventor is a commitment to use the funds in the development of the invention and to supply both accounting and technical reports to AOSTRA.

This continues to be a popular program with a total of 15 applications being reviewed during the year. Three of these applications were approved for funding as follows:

- Dwain Samuel, $50,000, Development of a Bucket Wheel Burner
- 355747 Alberta Ltd., $50,000, Development of a Sand Auger for Downhole Rotary Pumps
- Rod Pump Specialty Valve Ltd., $30,000, Development of an Improved Valve for Thermal Well Pumps

Grants awarded under IGAP have totalled $1,222,211 since the program was implemented.

17 TECHNOLOGY EXCHANGE

AOSTRA is in the process of negotiating two technology licenses in the fields of microwave technology for methane conversion and ultramicrobacteria for pore plugging in petroleum and non-petroleum applications.

18 PUBLICATIONS DEPARTMENT

In an effort to keep technical information on petroleum resources up-to-date and available to scientists and engineers, AOSTRA continued to publish extensively during the year.

Several large projects were undertaken and completed. These included *The Canadian Heavy Oil Association Reservoir Handbook* and the AOSTRA/USSR exchange tour report, *Observations and results of the recovery of bitumen and heavy oil by enhanced oil recovery (EOR) methods in the USSR*. AOSTRA continued to expand its Technical Publication Series with number seven of the series being published this year, the Alberta Geological Survey report, *Resource Characterization of the McMurray/ Wabiskaw Deposit in the Athabasca Central Region of Northeastern Alberta*.

The six previous publications in the AOSTRA Technical Publications Series are:

1. *Sync. ude Analytical Methods for Oil Sand and Bitumen Processing*
2. *The Thermodynamic and Transport Properties of Bitumens and Heavy Oils*
3. *Aquathermolysis: A Synopsis of Work on the Chemical Reaction Between Water (Steam) and Heavy Oil Sands During Simulated Steam Stimulation*
4. *Oil Sands Composition and Behaviour Research*
5. *A Review of Analytical Methods for Bitumens and Heavy Oils*
6. *AOSTRA Technical Handbook on Oil Sands, Bitumens and Heavy Oils*

The *AOSTRA Journal of Research*, published quarterly, continues to get technical information out to scientists and engineers involved in oil sands and heavy oil research. The *TARpaper*, also published quarterly, continues to highlight AOSTRA events and people at the leading edge of tar sands and heavy oil research, as well as related activities in the province. Its readership has increased to near 4000 subscribers. Subscriptions to both of these periodicals can be obtained through ALIS.

The Publications Department helped with the design of brochures for two China conferences which AOSTRA co-sponsored. Preprints and conference proceedings were also prepared.

Work on a book from Russia continued during the year. *Bitumen Deposits of*

Kazakhstan: Problems and Prospects, by N.K. Nadirov et al., is expected to be completed next year.

The Publications Department was involved in the production of much promotional material for the 5th UNITAR conference which will be held in Caracas in August 1991.

19 CONFERENCES, TRADE EXHIBITS, AND WORKSHOPS

Neftegaz 90 Technical Trade Show

- June 28–July 5, 1990
- Moscow, USSR

This exhibit featured the AOSTRA ATP model, graphics, and brochures (in Russian).

SPE Technical Conference and Exhibition

- September 23–26, 1990
- New Orleans, U.S.A.

This exhibit featured AOSTRA in situ thermal recovery, enhanced oil recovery, and the ATP.

Chem Tech 90 International Exhibition and Conference

- October 6–12, 1990
- New Delhi, India

AOSTRA and UMATAC coordinated a technical presentation to promote the ATP for hydrocarbon waste treatment.

University of the Saarland, Germany

AOSTRA hosted Professor Dr. Wolfgang Brücher July 12, 1990, to a visit of the Syncrude and Suncor open pit mining sites.

Trinidad and Tobago Oil Co. Ltd.

- Point-a-Pierre, Trinidad, W.I.

AOSTRA has agreed to undertake a mineral assay and batch test to ascertain ore quality for a proposed ATP feasibility study to exploit oil sands in Trinidad.

20 AWARDS

The Karl A. Clark Distinguished Service Award is presented to individuals who have made important contributions to the overall realization of the commercial potential of Alberta's oil sand resources. Currently the award is made by an external panel of five distinguished Canadians who review the nominations received in an open competition.

In 1990, the award was presented to Dr. Barry Mellon. Dr. Mellon's award consisted of a distinctive sculpture created specifically for this award by an Alberta artist, and the establishment of a $10,000 scholarship fund at the University of Calgary's Faculty of Business Administration in Dr. Mellon's name.

Chairs

In January 1990, Dr. William Costerton

Dr. Mellon (left) with Premier Getty at presentation ceremony.

of the Department of Microbiology of the University of Calgary, was awarded the NSERC Chair of Bacterial Biofilm Research. This important award was made in recognition of his internationally recognized contributions to the study of fouling of surfaces by bacteria. Of the 81 NSERC Chairs granted, 3 including this one are held in Alberta. The combined support of industry and AOSTRA was important in obtaining this award.

The term of the Chair is five years and annual support amounting to $604,600 is provided, 50% by a consortium of 18 companies, including AOSTRA, and a matching 50% by the National Science and Engineering Research Council (NSERC). AOSTRA's support for the Chair amounts to $40,000 per year.

In previous years, Dr. Costerton has received an AOSTRA Professorship Award of approximately $500,000 and research contracts amounting to $797,000 over an eight-year period. Dr. Costerton is responsible for many significant inventions including a patented process for selectively plugging subterranean formations. This process for increasing oil production from reservoirs and for containing contaminated ground waters is owned by AOSTRA.

21 AOSTRA LIBRARY AND INFORMATION SERVICES (ALIS)

AOSTRA Library and Information Services' multidisciplinary team of technical information officers and support staff in both Edmonton and Calgary provides fast, accurate information on oil sands, heavy oil, and enhanced recovery processes. Hard copies of all material are available at both sites.

AOSTRA's confidential information is also computerized and a hard-copy filing system is maintained. This information consists of:

- AOSTRA/Industry Field Pilot Projects;
- AOSTRA/University Research Program Agreements;
- AOSTRA Mining, Extraction, and Upgrading Projects;
- AOSTRA/ARC/Industry Program in Advanced Thermal Recovery;
- AOSTRA/ARC Strategic Program;
- AOSTRA/ARC Upgrading Study;
- AOSTRA/ARC Geology Program;
- IGAP (Inventors Grant Assistance Program);
- AOSTRA Patents;
- PRI Reports.

In addition, ALIS distributes the TARpaper, the AOSTRA Journal of Research, and all other AOSTRA publications

22 AOSTRA PATENTS

The following patents and patent applications are assigned to AOSTRA:

A) Canadian Patents

Patent No.	Date Issued	Patent Title
1,102,234	Jun 2/81	Gaseous and Solvent Additives for Steam Injection for Thermal Recovery of Bitumen from Tar Sands (D.A. Redford and M.R. Hanna)
1,120,418	Mar 23/82	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)
1,121,749	Apr 3/82	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk)
1,122,015	Apr 20/82	Process for Microbiologically Leaching Coke (T.R. Jack et al.)
1,134,174	Oct 26/82	Two-Phase Wet Steam Flowmeter (1) (D.S. Scott and E. Rhodes)
1,158,458	Dec 13/83	Variable Drive for Pump Jack (D.L. Buckler)
1,170,444	Jul 10/84	Use of Hydrogen-Free Carbon Monoxide with Steam in Recovery of Heavy Oil at Low Tem- peratures (J.B. Hyne and J.D. Tyrer)
1,171,382	Jul 24/84	Electrophoretic Process for Separating Aqueous Mineral Suspensions (R.A. Ritter)
1,184,022	Mar 19/85	Use of Surfactants to Improve Oil Recovery During Steam Flooding (E.E. Isaacs and D.R. Prowse)
1,189,444	Jun 25/85	Additive for Inclusion in a Heavy Oil Reservoir Undergoing Steam Injection (J.B. Hyne and P.D. Clarke)
1,206,465	Jun 24/86	Catalytic Sulfur Removal from Hydrocarbons (P.M. Boorman et al.)
1,210,358	Aug 26/86	Process for Upgrading a Heavy Viscous Hydrocarbon (I.H. Lutz) (Acres Davy McKee D.M. International, Inc., Houston, Texas)
1,220,646	Apr 21/87	Two-Phase/Flowmeter (2) (D.S. Scott and E. Rhodes)
1,225,129	Aug 4/87	Commutator (R.A. Ritter)
1,235,652	Apr 26/88	Method for Obtaining Horizontal Fractures in an Oil Reservoir (T. Harding et al.)
1,239,088	Jul 12/88	Method for Controlling Water Coning in Oil Wells (R.W. Luhning and K.R. Ronaghan)
1,241,293	Aug 30/88	Microwave Induced Catalytic Conversion of Methane to Ethylene and Hydrogen (J. Wan)
1,248,069	Jan 3/89	Apparatus for Continuously Separating Particulate Solids from Liquid Suspensions (R.A. Ritter)
1,277,936	Dec 18/90	Microbial Process for Selectively Plugging a Subterranean Formation (J.W.F. Costerton et al.)

B) Canadian Patent Applications

Application No.	Date Filed	Patent Application Title
2,015,459	Dec 19/90	Process for Confining Steam Injected into a Heavy Oil Reservoir (K.E. Kisman)
2,017,517	Dec 7/90	Surfactant Stabilizing Foams (C. Ayasse et al.)
2,018,739	Dec 28/90	Oil-Wetting Treatment for Reducing Water Coning in an Oil Reservoir (K.E. Kisman and B. Russell)
2,018,951	Dec 28/90	Water-Wetting Treatment for Reducing Water Coning in an Oil Reservoir (K.E. Kisman and B. Russell)
2,019,952	Dec 28/90	Treatment for Reducing Water Coning in an Oil Reservoir (K.E. Kisman and B. Russell)
2,021,595	Dec 7/90	Downhole Reciprocating Pump (T.A. Sudol et al.)
2,025,125-5	Sep 12/90	Improvements for Reducing Coke Deposition in Thermal Upgrading Processes (R.K. Lott, L.K. Lee, T. Cyr)
369,403-8	Jan 27/87	Wet Combustion Process (D.W. Bennion et al.)
379,072	Feb 22/83	Improved Process for Recovery of Residual Bitumen from Tailings from Oil Sand Extraction Plants (E.L. Tollefson and E. S. Hall)
517,837	Sep 9/86	Pressure-Up/Blowdown Combustion - A Channelled Reservoir Recovery Process (R.J. Hallam and J.K. Donnelly)
552,920	Nov 26/87	Steam Drive/Oil Recovery Process Involving Horizontal Boreholes (P. Toma)
574,694	Dec 20/88	Method and Apparatus for Measuring Fluid Viscosity (B.B. Maini)
604,267	Oct 30/89	Hydrocracking of Heavy Oils with Diluent and Homogeneous Additive (R.K. Lott et al.)
606,223	Dec 12/89	Recovery of Bitumen or Heavy Oil In Situ By Injection of Hot Water or Low Quality Steam Plus Caustic and Carbon Dioxide (A. S. McKay)
607,801	Dec 7/89	Piezometer Actuator Device and Method for Installation in a Borehole (J.P. Graham)
607,914	Feb 28/90	Wire-Wrapped Sandscreen for Down-hole Sand Exclusion (M.E. McCormack)

C) U.S. Patents

Patent No.	Date Issued	Patent Title
4,180,455	Dec 25/79	Process for Thermally Cracking a Heavy Hydrocarbon (W. Taciuk)
4,271,905	Jun 9/81	Gaseous and Solvent Additives for Steam Injection for Thermal Recovery of Bitumen from Tar Sands (D.A. Redford and M.R. Hanna)
4,280,879	Jul 28/81	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk)
4,285,773	Aug 25/81	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk - Lloydminster Version)
4,306,961	Dec 22/81	Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk - Tarsand Version)
4,312,234	Jan 26/82	Two-Phase Wet Steam Flow Meter (1) (D.S. Scott and E. Rhodes)
4,438,218	Mar 20/84	Catalytic Sulfur Removal from Hydrocarbons (P.M. Boorman et al.)
4,454,023	Jul/Aug/84	Process for Upgrading a Heavy Viscous Oil (Hydrocarbon) (I. Lutz) (Acres Davy McKee DM International, Inc., Houston)
4,458,759	Jul 10/84	Use of Surfactants to Improve Oil Recovery During Steam Flooding (E.E. Isaacs and D.R. Prowse)
4,487,264	Dec 11/84	Use of Hydrogen-Free Carbon Monoxide with Steam in Recovery of Heavy Oil at Low Temperatures (J.B. Hyne and J.D. Tyrer)
4,501,648	Feb 26/85	Electrophoretic Process for Separating Aqueous Mineral Suspensions (R.A. Ritter)
4,506,733	Mar 26/85	Additive for Inclusion in a Heavy Oil Reservoir Undergoing Steam Injection (J.B. Hyne and P.D. Clarke)
4,574,038	Mar 4/86	Microwave Induced Catalytic Conversion of Methane to Ethylene and Hydrogen (J. Wan)
4,574,643	Mar 11/86	Two-Phase Wet Steam Flowmeter (2) (D.S. Scott and E. Rhodes)
4,623,203	Nov 18/86	Commutator (R.A. Ritter)
4,623,442	Nov 18/86	Apparatus for Continuously Separating Particulate Solids from Suspensions (R.A. Ritter)
4,718,489	Jan 12/88	Pressure-up/Blowdown Combustion - A Channelled Reservoir Recovery Process (R.J. Hallam and J.K. Donnelly)
4,800,959	Jan 31/89	Microbial Process for Selectively Plugging a Sub- terranean Formation (J.W.F. Costerton)
4,890,482	Jan 2/90	Method and Apparatus for Measuring Fluid Viscosity (B.B. Maini)

D) U.S. Patent Applications

Application No.	Date Filed	Patent Application Title
06/294.523	Aug 20/81	Variable Speed Pump Jack (D.L. Buckler)
229,349	Jan 29/81	Wet Combustion Process (D.W. Bennion et al.)
7,558,530	Jul 26/90	Improved Downhole Reciprocating Pump (T.A. Sudol et al.)
784,933	Oct 7/85	Method for Controlling Water Coning in Oil Wells (R.W. Luhning and K.R. Ronaghan)
834,177	Feb 2/86	Method for Obtaining Horizontal Fractures in an Oil Reservoir (T. Harding et al.)
132,803	Dec 14/87	Steam Drive/Oil Recovery Process Involving Horizontal Boreholes (P. Toma)
229,008	Aug 5/88	Recovery of Bitumen or Heavy Oil In Situ by Injection of Hot Water or Low Quality Steam Plus Caustic and Carbon Dioxide (A.S. McKay)
07/349,527	May 9/89	Hydrocracking of Asphaltene-Rich Bitumen Residiums (L. Lewkowicz et al.)
07/375,373	Jul 3/89	Hydrocracking of Heavy Oils with Diluent and Homogeneous Additive (R.K. Lott et al.)
07/390,011	Jan 8/90	Piezometer Actuator Device and Method for Installation in a Borehole (J.P. Graham)
07/391,276	Oct 31/89	Wire-Wrapped Sand Screen for Downhole Sand Exclusion (M.E. McCormack)
07/648,875	Mar 6/91	Process for the Selective Conversion of the Asphaltenes in Bitumen Upgrading (K.J. Smith et al.)

E) Venezuela Patents

Patent No.	Date Issued	Patent Title
3729	Jun 10/80	Process for Microbiologically Leaching Coke (J. Zajic et al.)
785/81	May 9/81	Two Phase Wet Steam Flow Meter (D.S. Scott and E. Rhodes)
1299/82	Jul 21/82	Use of Hydrogen-Free Carbon Monoxide with Steam in Recovery of Heavy Oil at Low Temperatures (J.B. Hyne and J.D. Tyrer)
3714	Aug 1/86	Apparatus and Process for Recovery of Hydrocarbons from Inorganic Host Materials (W. Taciuk)
3970	Aug 5/86	Gaseous and Solvent Additives for Steam Injection for Thermal Recovery of Bitumen from Tar Sands (D.A. Redford and M.R. Hanna)
4102	Aug 7/86	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)
5278	Mar 18/87	Wet Combustion Process (D.W. Bennion, R.G. Moore and J.K. Donnelly)
6576	Apr 28/87	Additive for Inclusion in a Heavy Oil Reservoir Undergoing Steam Injection (J.B. Hyne and P.D. Clarke)

F) Mexico Patents

Patent No.	Date Issued	Patent Title
153182		Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

G) Mexico Patent Applications

Application No.	Date Filed	Patent Application Title
200,744	Mar 24/84	Process for Upgrading a Heavy Viscous Oil (Hydrocarbon) (I. Lutz) (Acres Davy McKee DM International, Inc., Houston)

H) European (EEC) Patents

Patent No.	Date Issued	Patent Title
0-028-666	Apr 6/83	Process and Apparatus for Thermally Heavy Hydrocarbon-Containing Liquids (W. Taciuk) (Belgium, France, Italy, Netherlands, and U.K.)
79,302542.0		(Sweden)
29-65-154.5		(Germany)
0076882	Jul 17/85	Two-Phase Flowmeter (1) (D.S. Scott and E. Rhodes)
84.301888.8	Mar 20/84	Process for Upgrading a Heavy Viscous Oil (Hydrocarbon) (I. Lutz) (Acres Davy McKee DM International, Inc., Houston)

I) Argentina Patent Applications

Application No.	Date Filed	Patent Application Title
279,427	Dec 21/79	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

J) Romania Patents

Patent No.	Date Issued	Patent Title
-78671	Oct 31/81	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

K) Turkey Patents

Patent No.	Date Issued	Patent Title
22129	May 13/86	Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

L) Japan Patents

Patent No.	Date Issued	Patent Title
12,248,916		Process and Apparatus for Thermally Processing Heavy Hydrocarbon-Containing Liquids (W. Taciuk)

PRIOR COMPANY PATENTS (for which AOSTRA has acquired certain licensing rights)

A) Canadian Patents

	Canadian Patent No.	Date Issued	Date Filed	Related U.S. Patent No.	Patent Titles
1.	1,125,649	Jan 15/82	Dec 19/79	4,234,042	Direct Combustion Stimulation of a Producing Well
2.	1,118,341	Feb 16/82	Sep 14/79	4,272,487	Indirect Thermal Stimulation of Producing Wells

B) U.S. Patents

	U.S. Patent No.	Date Issued	Date Filed	Related Canadian. Patent No.	Patent Titles
1.	3,964,547	Jun 22-76	Oct 29-74	972,679	Use of Tar as a Diverter in Steam Operations
2.	4,147,213	Apr 03-79	--	--	Combustion Air Injection Well
3.	4,234,042	Nov 18-80	Jun 11-79	1,125,649	Direct Combustion Stimulation of a Producing Well
4.	4,272,487	Jun 23-81	Jan 01-79	1,118,341	Indirect Thermal Stimulation of Producing Wells

Tables

Table 1

Oil Sands Technology and Research Fund
Summary of Funds Committed and Disbursed
As at March 31, 1991

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/90 to March 31/91	Balance
Institutional Research				
Alberta Research Council				
— Information Centre — ALIS	$ 7,325,168	$ 6,494,573	$ 830,576	$ 19
— Oil Sands Research Centre	30,363,886	29,207,053	1,007,060	149,773
— Sample Bank	1,937,788	1,817,900	119,888	–
— Regional Geological Program	5,475,280	4,964,754	450,626	59,900
— Hydrocarbon Program	3,701,849	3,266,729	399,956	35,164
— Strategic Research Program	7,444,256	5,871,542	1,572,679	35
Inventors Assistance Grant	1,489,545	1,094,211	128,000	267,334
University Contracts	36,255,633	31,321,852	2,762,546	2,171,235
Professorships and Chairs	4,121,109	3,961,494	40,000	119,615
New Graduate Assistance Program	690,000	486,401	180,222	23,377
Post Doctoral Fellowships	348,000	167,915	39,375	140,710
Scholarships and Fellowships	4,800,000	3,643,888	258,155	897,957
Lectureship Program	29,000	2,764	11,725	14,511
ARC Access Program	25,000	16,066	135	8,799
University Access Program	175,000	171,092	2,009	1,899
Program Planning and Evaluation	522,000	385,056	32,550	104,394
Petroleum Recovery Institute	7,589,252	5,587,567	1,000,000	1,001,685
Hydrogen Industry Council	125,000	–	125,000	–
Centre for Frontier Engineering Research	75,000	75,000	–	–
Computer Modeling Group	2,360,000	1,660,000	700,000	–
UNITAR Conference	379,000	289,809	2,441	86,750
UNITAR Management and Operations	268,895	209,945	58,950	–
Completed Projects	2,465,271	2,422,643	42,628	–
	$ 117,965,932	$ 103,118,254	$ 9,764,521	$ 5,083,157
Mining and Extraction				
Retorting				
— UMATAC	$ 19,752,208	$ 18,752,208	$ 935,000	$ 65,000
Saskatchewan Research Council	20,000	15,000	–	5,000
Terra Energy Sesa Project	500,000	376,448	96,973	26,579
Esso Resources OSLO Project	6,812,500	3,411,248	3,150,991	250,261
Burning Rock Oil Ltd.	60,000	–	14,428	45,572
Syncrude Canada Limited	955,000	481,448	400,000	73,552
Completed Projects	12,057,429	11,398,983	658,446	–
	$ 40,157,137	$ 34,435,335	$ 5,255,838	$ 465,964

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Summary of Funds Committed and Disbursed
As at March 31, 1991

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/90 to March 31/91	Balance
In Situ Oil Sands				
Peace River				
— Shell	$ 75,039,351	$ 74,934,003	$ 14,145	$ 91,203
Athabasca				
— Amoco	24,000,000	23,792,526	-	207,474
— Amoco/Petro-Canada	19,088,250	16,675,029	1,254,145	1,159,076
— Canterra Energy Ltd.	52,861,000	48,334,374	3,273,736	1,252,890
Cold Lake				
— BP	24,200,000	23,958,072	1,939	239,989
— BP/Petro-Canada	1,499,250	1,150,150	-	349,100
— Bow Valley Industries	14,200,000	13,732,837	83,858	383,305
— Suncor – Ft. Kent	400,000	118,979	(3,022)	284,043
Simtech Consulting	75,260	60,460	10,336	4,464
Fekete Thermal Software Program	100,000	97,216	-	2,784
Simons Consulting — Coning Project	521,200	75,203	58,180	387,817
Engineering Studies Program	500,000	377,887	85,378	36,735
Site Studies	375,000	45,181	81,436	248,383
Peace River Task Force	100,000	31,177	-	68,823
Centre for Frontier Engineering	30,000	18,000	-	12,000
C.E.F.R. — Sand Control	150,000	-	25,000	125,000
Mazzei Oil and Gas	470,000	-	460,211	9,789
Petro-Canada — Hangingstone Project	50,000	-	-	50,000
Completed Projects	10,564,382	10,522,415	41,967	-
	$ 224,223,693	$ 213,923,509	$ 5,387,309	$ 4,912,875
Underground Access				
Athabasca				
— UTF Project	$ 76,956,947	$ 59,358,382	$ 14,875,922	$ 2,722,643
— Completed Projects	5,108,264	5,108,264	-	-
	$ 82,065,211	$ 64,466,646	$ 14,875,922	$ 2,722,643
Carbonate Trend				
Buffalo Creek				
— Union Oil	$ 31,585,000	$ 31,286,351	$ 29,953	$ 268,696
Completed Projects	308,082	308,082	-	-
	$ 31,893,082	$ 31,594,433	$ 29,953	$ 268,696
Heavy Oil				
Petro-Canada	$ 14,308,046	$ 13,974,159	$ 59,311	$ 274,576
Alberta Energy Company	7,941,500	7,314,478	166,182	460,840
Norcen International Ltd.	4,130,000	4,778,591	(649,271)	680
PanCanadian Petroleum	1,500,000	1,039,186	73,775	387,039
Completed Projects	239,674	239,674	-	-
	$ 28,119,220	$ 27,346,088	$ (350,003)	$ 1,123,135

Table 1

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Summary of Funds Committed and Disbursed
As at March 31, 1991

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/90 to March 31/91	Balance
Enhanced Recovery Conventional Oil				
Vikor Resources Ltd.	$ 3,900,000	$ 4,103,725	$ (374,534)	$ 170,809
Hudson's Bay Oil & Gas	2,462,500	2,226,155	197,812	38,533
Robinson Slim Tube Test	192,573	155,990	30,043	6,540
Saskatchewan Research Council	225,000	150,000	75,000	–
PRI EOR Initiatives Program	400,000	370,135	29,343	522
PRI Pulp and Paper Study	20,000	–	13,798	6,202
Pfizer Rundell Horizontal Well	800,000	–	–	800,000
Strategic Research EOR	300,000	7,700	110,350	181,950
Donnely Gasification Study	50,000	–	–	50,000
Amoco — Combustion Study	25,000	–	–	25,000
Petro Phyic Drilling	30,000	–	3,806	26,194
Completed Projects	3,823,641	2,796,855	1,026,786	–
	$ 12,228,714	$ 9,810,560	$ 1,112,404	$ 1,305,750
Bitumen Upgrading				
Residue Utilization Project	$ 1,398,232	$ 1,216,004	$ 18,790	$ 163,438
A.U.R.D. Upgrading Demonstration Pilot	300,000	–	195,453	104,547
Canadian Energy — Co-Processing	297,500	–	169,776	127,724
Coal – Oil Processing	50,000	8,368	31,182	10,450
Petro-Canada/CANMET Project	450,000	392,201	6,370	51,429
R.T.M. Engineering Ltd.	49,000	–	26,942	22,058
Lummus Crest Inc.	1,444,000	712,890	561,352	169,758
Completed Projects	24,479,806	24,427,399	52,407	–
	$ 28,468,538	$ 26,756,862	$ 1,062,272	$ 649,404
Technology Transfer and Commercialization				
Technology Transfer and Commercialization	$ 880,000	$ 525,727	$ 381,455	$ (27,182)
Umatac/SPP — Commercialization	1,000,000	–	1,027,505	(27,505)
ATP — Commercialization	250,000	–	225,197	24,803
Comparative Economic Evaluation	300,000	–	17,759	282,241
5-Ton/Hr. — Umatac ATP Processor	5,000,000	–	275,612	4,724,388
A.W.A.C.T. — Demonstrations	40,000	–	–	40,000
	$ 7,470,000	$ 525,727	$ 1,927,528	$ 5,016,745
Environmental Research				
W.T.C. Water Treatment Project	$ 700,000	$ 434,818	$ 110,742	$ 154,440
Monenco	259,253	67,665	–	191,588
Sludge Fundamental Consortium	200,000	–	122,928	77,072
Canadian Petroleum Association Oily Solids	30,000	–	20,000	10,000
Carbon Dioxide Disposal	50,000	–	13,526	36,474
Environmental Audits	85,000	–	–	85,000
Environmental Research Centre	250,000	–	250,000	–
	$ 1,574,253	$ 502,483	$ 517,196	$ 554,574

Table 1

Oil Sands Technology and Research Fund
Summary of Funds Committed and Disbursed
As at March 31, 1991

Project	Funds Committed	Prior Years' Disbursements	Disbursements April 1/90 to March 31/91	Balance
Technology Handling				
Database Administration	$ 4,524,165	$ 4,130,700	$ 258,108	$ 135,357
AOSTRA Journal	539,773	484,061	38,565	17,147
Patent Costs	1,245,000	924,574	255,109	65,317
AOSTRA Publication Series	166,900	57,392	46,006	63,502
AOSTRA Technical Handbook	100,000	91,497	143	8,360
AOSTRA 15 Year Review	645,510	612,176	28,833	4,501
Completed Projects	91,865	91,865	–	–
	$ 7,313,213	$ 6,392,265	$ 626,764	$ 294,184
Training Activities	$ 3,575,000	$ 2,622,444	$ 427,005	$ 525,551
International Activities	$ 2,862,575	$ 2,029,052	$ 311,499	$ 522,024
Authority Costs	$ 3,298,708	$ 2,461,534	$ 517,638	$ 319,536
Totals	$ 591,215,276	$ 525,985,192	$ 41,465,846	$ 23,764,238

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Sixteen-Year Summary
For the years ended March 31

	1991	1990	1989
Revenue			
Alberta General Revenue Fund	$ 25,394,000	$ 29,349,000	$ 26,100,000
Alberta Heritage Savings Trust Fund	–	5,151,000	9,900,000
Technology Sales	534,321	664,347	774,027
	$ 25,928,321	$ 35,164,347	$ 36,774,027
Expenditures			
Institutional Research			
Alberta Research Council			
— Information Centre — ALIS	$ 830,576	$ 798,006	$ 714,129
— Oil Sands Research Centre	1,007,060	1,215,172	1,312,005
— Sample Bank	119,888	111,760	144,000
— Regional Geological Program	450,626	367,878	497,521
— Hydrocarbon Program	399,956	401,897	388,600
— Strategic Research Program	1,572,679	1,447,570	1,586,666
Inventors Assistance Grant	128,000	200,000	274,750
University Contracts	2,762,546	2,373,413	2,864,891
Professorships and Chairs	40,000	40,000	743
New Graduate Assistance Program	180,222	211,285	201,518
Post Doctoral Fellowships	39,375	76,875	22,500
Scholarships and Fellowships	258,155	398,076	419,280
Lectureship Program	11,725	2,764	–
ARC-Access Program	135	–	5,896
University Access Program	2,009	(146)	(2,930)
Program Planning and Evaluation	32,550	19,276	39,160
Petroleum Recovery Institute	1,000,000	1,000,000	700,000
Hydrogen Industry Council	125,000	–	–
Centre for Frontier Engineering Research	–	–	25,000
Computer Modeling Group	700,000	1,000,000	220,000
UNITAR Conference	2,441	96,140	23,475
UNITAR Management and Operations	58,950	99,853	110,092
Completed Projects	42,628	–	–
	$ 9,764,521	$ 9,859,819	$ 9,547,296

1988	1987	1986 and Prior	Total
$ 26,900,000	$ 34,700,000	$ -	$ 142,443,000
20,800,000	31,400,000	351,449,032	418,700,032
1,325,060	1,227,125	15,623,212	20,148,092
$ 49,025,060	$ 67,327,125	$ 367,072,244	$ 581,291,124

$ 699,180	$ 591,097	$ 3,692,161	$ 7,325,149
1,430,990	1,972,980	23,275,906	30,214,113
153,423	155,588	1,253,128	1,937,787
464,075	517,955	3,117,324	5,415,379
374,383	773,341	1,328,508	3,666,685
1,588,050	1,249,256	-	7,444,221
109,000	82,562	427,899	1,222,211
3,018,722	2,952,754	20,112,073	34,084,399
91,120	411,389	3,418,241	4,001,493
65,750	7,847	-	666,622
22,500	-	46,040	207,290
418,639	336,883	2,071,011	3,902,044
-	-	-	14,489
723	1,213	8,234	16,201
(95)	8,697	165,567	173,102
-	54,243	272,377	417,606
700,000	1,000,000	2,187,567	6,587,567
-	-	-	125,000
25,000	-	25,000	75,000
220,000	220,000	-	2,360,000
104,588	65,605	-	292,249
-	-	-	268,895
17,000	84,984	2,320,660	2,465,272
$ 9,503,048	$ 10,486,394	$ 63,721,696	$ 112,882,774

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Sixteen-Year Summary
For the years ended March 31

	1991	1990	1989
Mining and Extraction			
Retorting			
— Umatac	$ 935,000	$ 999,332	$ 1,004,649
Saskatchewan Research Council	–	15,000	–
Terra Energy-Sesa Project	96,972	113,673	192,389
Esso Resources OSLO Project	3,150,991	1,955,247	1,118,220
Burning Rock Oil Ltd.	14,428	–	–
Syncrude Canada	400,000	187,151	294,297
Completed Projects	658,447	487,418	345,652
	$ 5,255,838	$ 3,757,821	$ 2,955,207
In Situ Oil Sands			
Peace River			
— Shell	$ 14,145	$ 16,580	$ 175,484
Athabasca			
— Amoco	–	–	–
— Amoco/Petro-Canada	1,254,145	1,338,535	1,372,878
— Canterra Energy Ltd.	3,273,736	5,220,248	6,641,372
Cold Lake			
— BP	1,939	10,105	13,971
— BP/Petro-Canada	–	–	–
— Bow Valley Industries	83,858	761,256	884,225
— Suncor — Fort Kent	(3,022)	–	–
Simtech Consulting	10,336	18,786	9,043
Fekete Thermal Software Program	–	–	97,216
Simons Consulting — Coning Project	58,180	–	75,203
Engineering Studies Program	85,378	172,495	186,274
Sites Studies	81,436	22,303	22,878
Peace River Task Force	–	31,177	–
Centre for Frontier Engineering	–	18,000	–
C.E.F.R. — Sand Control	25,000	–	–
Mazzei Oil and Gas	460,211	–	–
Completed Projects	41,967	198,894	44,226
	$ 5,387,309	$ 7,808,379	$ 9,522,770

1988	1987	1986 and Prior	Total
$ 1,378,265	$ 1,182,251	$ 14,187,710	$ 19,687,207
–	–	–	15,000
70,386	–	–	473,420
–	–	–	6,224,458
–	–	–	14,428
–	–	–	881,448
809,657	3,855,714	6,238,323	12,395,211
$ 2,258,308	$ 5,037,965	$ 20,426,033	$ 39,691,172
$ 113,028	$ 12,299,010	$ 62,329,900	$ 74,948,147
(27,148)	5,432	23,814,243	23,792,527
2,069,863	3,953,698	7,940,055	17,929,174
8,700,700	3,299,311	24,472,743	51,608,110
82,402	2,589,985	21,261,608	23,960,010
–	35,349	1,114,800	1,150,149
841,980	2,833,056	8,412,321	13,816,696
–	37,883	81,096	115,957
4,299	9,442	18,890	70,796
–	–	–	97,216
–	–	–	133,383
19,118	–	–	463,265
–	–	–	126,617
–	–	–	31,177
–	–	–	18,000
–	–	–	25,000
–	–	–	460,211
679,297	19,045	9,580,955	10,564,384
$ 12,483,539	$ 25,082,211	$ 159,026,611	$ 219,310,819

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Sixteen-Year Summary
For the years ended March 31

	1991	1990	1989
Underground Access			
Athabasca			
— UTF Project	$ 14,875,922	$ 1,443,614	$ 3,091,270
— Completed Projects	-	-	-
	$ 14,875,922	$ 1,443,614	$ 3,091,270
Carbonate Trend			
Buffalo Creek			
— Union Oil	$ 29,953	$ 57,911	$ 80,747
Completed Projects	-	-	-
	$ 29,953	$ 57,911	$ 80,747
Heavy Oil			
Petro-Canada	$ 59,311	$ 180,651	$ (176)
Alberta Energy Company	166,182	18,304	774,287
Norcen International Ltd.	(649,271)	(515,121)	(548,382)
PanCanadian Petroleum	73,775	70,854	207,119
Completed Projects	-	-	-
	$ (350,003)	$ (245,312)	$ 432,848
Enhanced Recovery Conventional Oil			
Vikor Resources Ltd.	$ (374,534)	$ (126,283)	$ 931,941
Hudson's Bay Oil & Gas	197,812	144,777	236,523
Robinson Slim Tube Test	30,043	-	32,382
Canterra's Solids Disposition Project	1,244	37,877	16,869
Saskatchewan Research Council	75,000	75,000	65,000
PRI EOR Initiatives Program	29,343	26,462	343,673
PRI — Pulp and Paper Study	13,798	-	-
Strategic Research EOR	110,350	7,700	-
Petro Physic Drilling	3,806	-	-
Completed Projects	1,025,542	533,874	250,000
	$ 1,112,404	$ 699,407	$ 1,876,388

1988	1987	1986 and Prior	Total
$ 3,764,839	$ 11,248,413	$ 39,810,245	$ 74,234,303
–	–	5,108,264	5,108,264
$ 3,764,839	$ 11,248,413	$ 44,918,509	$ 79,342,567
$ 255,743	$ 2,860,676	$ 28,031,274	$ 31,316,304
–	137	307,945	308,082
$ 255,743	$ 2,860,813	$ 28,339,219	$ 31,624,386
$ (29,809)	$ 314,067	$ 13,608,369	$ 14,132,413
165,875	585,204	5,671,867	7,381,719
(1,188,165)	6,914,180	116,079	4,129,320
66,140	145,688	549,386	1,112,962
–	–	239,672	239,672
$ (985,959)	$ 7,959,139	$ 20,185,373	$ 26,996,086
$ (22,200)	$ 484,889	$ 2,835,378	$ 3,729,191
277,211	129,714	1,437,929	2,423,966
116,049	7,559	–	186,033
18,037	81,213	–	155,240
10,000	–	–	225,000
–	–	–	399,478
–	–	–	13,798
–	–	–	118,050
–	–	–	3,806
225,594	602,875	1,030,516	3,668,401
$ 624,691	$ 1,306,250	$ 5,303,823	$ 10,922,963

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Sixteen-Year Summary
For the years ended March 31

	1991	1990	1989
Bitumen Upgrading			
Residue Utilization Project	$ 18,790	$ 16,023	$ 17,475
A.U.R.D. Upgrading Demonstration Pilot	195,453	–	–
Canadian Energy — Co-Processing	169,776	–	–
Coal — Oil Processing	31,182	(16,406)	24,774
Petro-Canada/CANMET Project	6,370	392,201	–
R.T.M. Engineering Ltd.	26,942	–	–
Lummus Crest Inc.	561,352	712,891	–
Completed Projects	52,407	438,114	740,888
	$ 1,062,272	$ 1,542,823	$ 783,137
Technology Transfer and Commercialization			
Technology Transfer and Commercialization	$ 381,455	$ 323,753	$ 157,866
Umatac/SPP — Commercialization	1,027,505	–	–
ATP — Commercialization	225,197	–	–
Comparative Economic Evaluation	17,759	–	–
5-Ton/H. – Umatac ATP Processor	275,612	–	–
	$ 1,927,528	$ 323,753	$ 157,866
Environmental Research			
W.T.C. Water Treatment Project	$ 110,742	$ 59,818	$ 34,599
Monenco	–	67,665	–
Sludge Fundamental Consortium	122,928	–	–
Canadian Petroleum Association	20,000	–	–
Carbon Dioxide Disposal	13,526	–	–
Environmental Research Centre	250,000	–	–
	$ 517,196	$ 127,483	$ 34,599

1988	1987	1986 and Prior	Total
$ 161,169	$ 210,187	$ 811,150	$ 1,234,794
–	–	–	195,453
–	–	–	169,776
–	–	–	39,550
–	–	–	398,571
–	–	–	26,942
–	–	–	1,274,243
3,531,881	9,701,395	10,015,121	24,479,806
$ 3,693,050	$ 9,911,582	$ 10,826,271	$ 27,819,135
$ 44,108	$ –	$ –	$ 907,182
–	–	–	1,027,505
–	–	–	225,197
–	–	–	17,759
–	–	–	275,612
$ 44,108	$ –	$ –	$ 2,453,255
$ 340,400	$ –	$ –	$ 545,559
–	–	–	67,665
–	–	–	122,928
–	–	–	20,000
–	–	–	13,526
–	–	–	250,000
$ 340,400	$ –	$ –	$ 1,019,678

Table 2

Oil Sands Technology and Research Fund
Statement of Revenue
Expenditure and Fund Balance

Sixteen-Year Summary
For the years ended March 31

	1991	1990	1989
Technology Handling			
Data Base Administration	$ 258,108	$ 311,959	$ 122,285
AOSTRA Journal	38,565	42,340	38,320
Patent Costs	255,109	211,702	110,252
AOSTRA Publication Series	46,006	41,897	5,695
AOSTRA Technical Handbook	143	55,148	31,130
AOSTRA 15 Year Review	28,833	612,177	-
Completed Projects	-	-	-
	$ 626,764	$ 1,275,223	$ 307,682
Training Activities	$ 427,005	$ 440,325	$ 380,107
International Activities	$ 311,499	$ 178,880	$ 167,161
Authority Costs	$ 517,638	$ 228,811	$ 217,867
	$ 41,465,846	$ 27,498,937	$ 29,554,945
Excess of Revenue over Expenditures	$ (15,537,525)	$ 7,665,410	$ 7,219,082
Fund Balance at Beginning of Period	$ 29,377,609	$ 21,712,199	$ 14,493,117
Fund Balance at End of Period	$ 13,840,084	$ 29,377,609	$ 21,712,199

1988	1987	1986 and Prior	Total
$ 240,945	$ 498,062	$ 2,957,448	$ 4,388,807
46,185	45,310	311,907	522,627
102,620	15,730	484,270	1,179,683
9,800	–	–	103,398
5,000	–	219	91,640
–	–	–	641,010
–	–	91,865	91,865
$ 404,550	$ 559,102	$ 3,845,709	$ 7,019,030
$ 42,364	$ 219,758	$ 1,539,891	$ 3,049,450
$ 77,930	$ 71,687	$ 1,533,395	$ 2,340,552
$ 298,554	$ 448,223	$ 1,268,080	$ 2,979,173
$ 32,805,165	$ 75,191,537	$ 360,934,610	$ 567,451,040
$ 16,219,895	$ (7,864,412)	$ 6,137,634	$ 13,840,084
$ (1,726,778)	$ 6,137,634	$ –	$ –
$ 14,493,117	$ (1,726,778)	$ 6,137,634	$ 13,840,084

Auditor's Report and Financial Statement

Alberta Oil Sands
Technology and Research Authority
Oil Sands Technology and Research Fund
Financial Statements
March 31, 1991

Auditor's Report

Balance Sheet

Statement of Revenue, Expenditure and Fund Balance

Notes to the Financial Statements

AUDITOR'S REPORT

To the Members of the Alberta Oil Sands Technology and Research Authority

I have audited the balance sheet of the Alberta Oil Sands Technology and Research Authority — Oil Sands Technology and Research Fund as at March 31, 1991 and the statement of revenue, expenditure and fund balance for the year then ended. These financial statements are the responsibility of the Authority's management. My responsibility is to express an opinion on these financial statements based on my audit.

I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In my opinion, these financial statements present fairly, in all material respects, the financial position of the Fund as at March 31, 1991 and the results of its operations and the changes in its financial position for the year then ended in accordance with generally accepted accounting principles.

Donald D. Salmon

FCA
Auditor General

Edmonton, Alberta
June 20, 1991

Alberta Oil Sands Technology and Research Authority
Oil Sands Technology and Research Fund

Balance Sheet

As At March 31, 1991

ASSETS	1991	1990
Current:		
Cash	$ 24,042,173	$ 35,991,145
Deposits on projects, net (Note 3)	646,449	915,595
Accounts receivable	874,000	3,740,614
	$ 25,562,622	$ 40,647,354

LIABILITIES AND FUND BALANCE		
Current:		
Accounts payable	$ 9,731,422	$ 10,224,549
Holdbacks payable	1,991,116	1,045,196
	11,722,538	11,269,745
Fund balance	13,840,084	29,377,609
	$ 25,562,622	$ 40,647,354

The accompanying notes are part of these financial statements.

Alberta Oil Sands Technology and Research Authority
Oil Sands Technology and Research Fund

Statement of Revenue, Expenditure and Fund Balance

For the Year Ended March 31, 1991

	1991	*1990*
Revenue:		
Contributions by the Province of Alberta:		
— General Revenue Fund	$ 25,394,000	$ 29,349,000
— Alberta Heritage Savings Trust Fund	-	5,151,000
Technology sales	534,321	664,347
	$ 25,928,321	$ 35,164,347
Expenditure:		
Underground access	14,875,922	1,443,614
Institutional research	9,764,521	9,859,819
In situ oil sands	5,387,309	7,808,379
Mining and extraction	5,255,838	3,757,821
Technology transfer and commercialization	1,927,528	323,753
Enhanced recovery	1,112,404	699,407
Bitumen upgrading	1,062,272	1,542,823
Technology handling	626,764	1,275,223
Authority costs	517,638	228,811
Environment	517,196	127,483
Training activities	427,005	440,325
International activities	311,499	178,880
Carbonate trend	29,953	57,911
Heavy oil	(350,003)	(245,312)
	$ 41,465,846	$ 27,498,937
Excess (deficiency) of revenue over expenditure for the year	(15,537,525)	7,665,410
Fund balance at beginning of year	29,377,609	21,712,199
Fund balance at end of year	$ 13,840,084	$ 29,377,609

Alberta Oil Sands Technology and Research Authority
Oil Sands Technology and Research Fund

Notes to the Financial Statements

March 31, 1991

Note 1 Authority

The Alberta Oil Sands Technology and Research Authority operates under the authority of the Oil Sands Technology and Research Authority Act, Chapter O-6, Revised Statutes of Alberta 1980.

Note 2 Significant Accounting Policies And Reporting Practices

Expenditures are stated net of recoveries arising from agreements with various participants. Interest earned on cash balances is credited to the General Revenue Fund, and is not reflected in these financial statements. A statement of changes in financial position is not provided as disclosure in these financial statements is considered to be adequate.

Note 3 Deposits On Projects

This amount represents the net excess of cash calls on projects over actual expenditures.

Note 4 Potential Recoveries

The following amounts represent maximum potential future recoveries from the participants in respect of projects funded by the Authority:

	1991	1990
Shell Canada Resources Limited (In situ oil sands)		
— PRISP Project	$ 12,200,000	$ 12,200,000
— Sale of 50% interest in PRISP Project	12,200,000	12,200,000
Norcen International Ltd. (Heavy oil)		
— BODO Steam Pilot Project	4,129,000	4,779,000
Vikor Resources Ltd. (Enhanced recovery)		
— Joffre Project	3,792,000	4,104,000
	$ 32,321,000	$ 33,283,000

Recovery of these amounts is dependent on generation of sufficient revenue by the projects. Due to the uncertainty concerning the amounts of recoveries which may ultimately be generated, these amounts have not been included as a receivable in these financial statements and will be offset against expenditures in the year of receipt.

Note 5 Commitments

The Authority had outstanding commitments as at March 31, 1991 totalling $23,764,000 (1990 $32,770,00) for approved projects.

Note 6 Contingent Liabilities

The Authority is involved in a number of legal proceedings. Claims amounting to approximately $2,100,000 have been filed against the Authority. In the opinion of management, the disposition of these claims is not likely to materially affect the financial position of the Authority. Settlements, if any, will be reflected as expenditure in the year the settlement occurs.

Note 7 Administration Costs

The following costs incurred in the administration of the Authority have been borne by the General Revenue Fund and are not reflected in these financial statements.

	1991	1990
Salaries and wages	$ 2,382,809	$ 2,146,443
Rental of property and equipment	405,954	386,254
Employee benefits	364,464	333,990
Fees and commissions	273,484	227,943
Travelling and hospitality	174,137	174,274
Materials and supplies	94,264	75,063
Equipment maintenance	27,202	12,607
Telephone and telegraph	18,886	16,318
Advertising	10,154	(1,168)
Freight, express and postage	8,915	19,421
Insurance premiums	4,569	4,521
Grants	4,000	3,050
Furniture and equipment purchases	2,878	2,351
Staff relocation costs	–	11,511
	$ 3,771,716	$ 3,412,578

Note 8 Comparative Figures

The 1990 figures have been reclassified where necessary to conform to 1991 presentation.

Note 9 Approval Of Financial Statements

These financial statements were approved by management.